'The' pathway towards the elite level in Dutch basketball

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A multidimensional and longitudinal study on the development of talented youth basketball players

Sanne te Wierike

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A multidimensional and longitudinal study on the development of talented youth basketball players

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Chapter 1

General introduction

Background

Rik Smits, the Dunkin' Dutchman, is a great example of a Dutch basketball player who has achieved the international elite level of performance in adulthood. The 2.24 m tall center played twelve years for the Indiana Pacers in the National Basketball Association (NBA) of the United States of America. He started his career in the Netherlands at PSV/Almonte Eindhoven and then moved to the United States of America to play for Marist College. After only a few years he was scouted by the NBA. Due to a combination of his height and the great effort he put in, for example by spending extra training hours before and after the regular training sessions with his team, he became the most successful Dutch basketball player up to today and is an example for many youth players[1].

In the Netherlands, sport has a high priority as illustrated by the ambition of the NOC*NSF (Dutch Olympic Committee*Dutch Sports Federation) to rank among the top-ten sports countries in the world. Scientific research related to the development of talented youth athletes towards the elite level in adulthood can be helpful to reach this goal. As acquiring expertise is a long-term process influenced by various factors, a multidimensional approach is recommended in research related to talent development[2-4]. The research described in this thesis focuses on the performance development of talented youth male basketball players aged 13-19 years. Multidimensional performance characteristics of basketball players are measured with the 'Groningen Basketball Test Battery'. The tests are related to biological maturation (sitting height, leg length, and body mass for calculating age at peak height velocity (PHV)), anthropometrical (height, wingspan, fat percentage, lean body mass), physiological (sprint, repeated sprint, change-of-direction speed, lower body explosive strength, interval endurance capacity), technical (dribble, repeated dribble, ball control), and psychosocial characteristics (reflection, planning, evaluation, self-monitoring, effort, and self-efficacy (aspects of self-regulation)). The basketball players participating in this thesis were selected by coaches and trainers for a talent development program. In literature, a talented athlete is considered as a player who performs better than his peers, and has the potential to achieve the elite level in adulthood[2,5,6]. In order to consider the potential of basketball players, and to take into account the unstable, non-linear development of performance characteristics, this thesis seeks for appropriate statistical and methodological analyzes[2,4,7,8]. A total of 99 talented youth basketball players (aged 13-19) are monitored during five consecutive seasons (2008-2009 to 2012-2013). Sixteen characteristics were measured two or three times each season, resulting in 6448 data points. So, a multidimensional and longitudinal approach was used, which is more and more common in research related to talent development[9]. The results of this thesis give insight into the performance development of talented basketball players, and will provide recommendations for basketball coaches, trainers, scouts, and policy makers to guide talented youth basketball players towards the elite level of performance in adulthood.

Theoretical framework

The performance development (i.e., accumulation of performance until a certain moment) of talented youth basketball players is the result of their personal characteristics, which are influenced by characteristics of the basketball game and the environment (figure 1.1). The interaction between these components, i.e., the basketball game, the environment, and the basketball player himself, related to the effects of maturation, self-regulation of learning and training, together with a component of chance, determines the performance development of each individual basketball player over time[2].

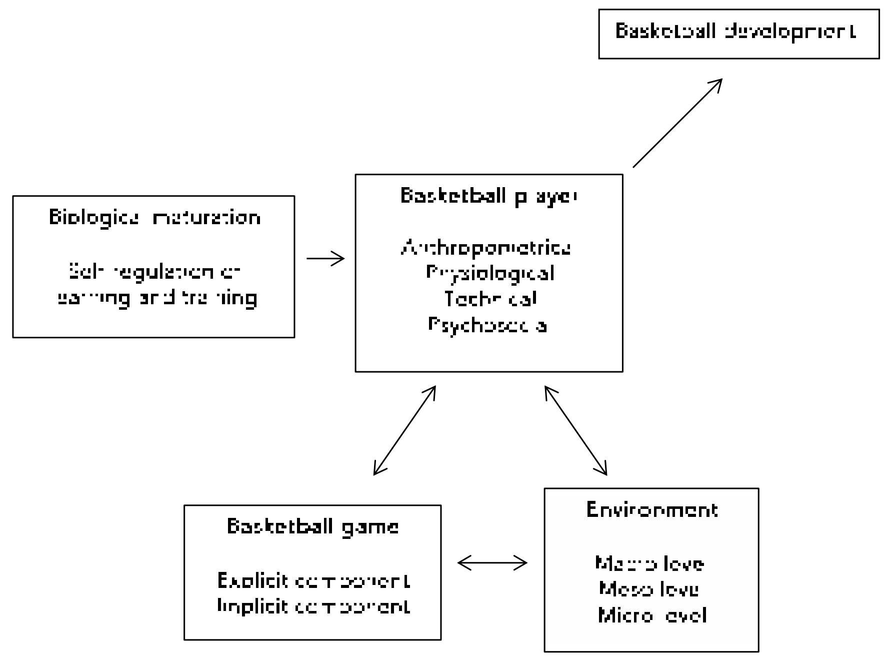

Figure 1.1: Theoretical framework to illustrate the performance development of talented youth basketball players[2,10].

Basketball game

The requirements of the game, in which players need to optimize their performance, are considered across two levels. First, the explicit game components refer to the rules imposed by the Dutch Basketball Federation that specify the basketball game[11]. Basketball is an intermittent team sport in which two teams of five players on the court try to score points by shooting the ball in the basket of the other team. The aim is to score more points than the opposing team at the end of the four ten minute quarters play time (as played in the Dutch basketball league).

Second, the different positional tasks within a team can be considered as the implicit game components. The five players within a team have different roles during the game in order to achieve their common goal, i.e., winning the game. The guards are responsible for the start of the offence for their team (i.e., the playmakers) and try to disrupt the offence of the other team. The forwards fulfill a more versatile playing position. Their task is, for example, to score either from close to the basket, or further away when the team is in offence, and hinder passes when the team is in defense. Finally, the center position is often located near the basket. The main task of this player is to score points during their team's offence. During the defense centers have to prevent the opponents from scoring by, for example, blocking their shots at the basket. Centers also fulfill a major role in rebounding the ball after missed shots of the opponents.

Environment

Players need a suitable learning environment (meso level) in order to develop performance characteristics necessary for playing basketball at the highest level[12]. This thesis focuses on basketball players competing in the U14, U16, U18, or U20 category at the highest youth level in the Dutch basketball competition (Eredivisie). All players are selected for the regional training center (RTC) in the north of the Netherlands, as introduced by the Dutch Basketball Federation in 2011. The aim of these RTC's is to create an environment, i.e., a talent development program, in which the performance development of players is stimulated[13]. RTC's offer guidance and facilities for players as ideally as possible. For example, players are provided with good training facilities, medical care, and educational support.

Basketball player

In order to play at the top level of the Dutch youth competition, basketball players need to possess a high level of multidimensional performance characteristics (i.e., anthropometrical, physiological, technical, and psychosocial) which are related to the basketball game[2]. Anthropometrics such as height and weight are of great magnitude in basketball partly due to the fact that it is a contact sport in which players are directly faced with their opponents. The importance of height and weight is demonstrated by Torres-Unda et al. (2013) and Hoare (2000) by showing that the best basketball players were taller and heavier compared to their less successful counterparts[14,15].

Besides the importance of anthropometrical characteristics, physiological characteristics are essential as well due to the high physiological demands in basketball[16]. Basketball players have to perform different types of movements during a game (e.g., sprinting, dribbling, passing, shooting), with a change of movement every 2-3 seconds[16]. This indicates that speed and change-of-direction speed are important skills for youth basketball players[17]. Research has confirmed this by showing that elite players are faster on sprint tests compared to non-elite players[14]. Moreover, repeated sprint ability is a key factor in basketball due to the intermittent character of the game. Repeated sprint ability consists of maximal sprints of short durations interspersed with little recovery in between[18].

Especially typical for basketball is that players are able to maintain their speed while (repeated) dribbling with the ball. This technical skill is discriminative between the performances of elite and sub-elite youth basketball players (in favor of the elites), indicating its importance[14]. Basketball players should be able to dribble with the ball in a forward, backward, and sideward direction (ball control) to, for example, pass by the opponents on the court.

The last performance characteristics investigated in this thesis are the psychosocial ones, which recently have received an increasing amount of attention within talent development in sports[19,20]. Self-regulation is one of the psychosocial concepts that appears to be related to excellent performance. A self-regulated athlete is someone who is metacognitive, motivationally, and behaviorally active in his own learning process[21-23]. For example, a basketball player who wants to improve a skill that is highly important for his position has to be aware of his own weak and strong points related to this skill, has to make a plan of how he wants to improve it, and has to monitor his progress and evaluate the results of his plan. Research has shown that self-regulatory skills, especially reflection, are important to realize one's potential[21,24,25].

The dynamic character of performance development

The interaction between influences of the game, environment, and player as described above, as well as the influences from biological maturation and self-regulation of learning and training is dynamic, and affects the performance development of basketball players over time. For example, the effects of maturation influence the performance characteristics of players (figure 1.1). The target group of this thesis consists of players from the age of 13 which characterizes them as a heterogeneous group regarding maturational aspects[26]. Maturation consists of structural and functional changes of the body during the development towards maturity[27-29]. Due to the differences in timing (indicated by the age at PHV) and tempo of maturation, players of the same chronological age may temporarily differ in their anthropometrical as well as in their physiological development[26,30].

In addition, players during PHV have an increased vulnerability for traumatic injuries[31]. Dick et al. (2007) showed that knee injuries, for example anterior cruciate ligament (ACL) injuries, are the most common severe injuries in male basketball (i.e., resulting in a loss of more than ten days of participation)[32]. More than 60% of the ACL injuries occur without contact with other players[32]. Pivoting, decelerations, and landing from a vertical leap are typical examples of actions in basketball which are risk factors for tearing the ACL[33]. Injuries like these can be seen as an unpleasant hindering of the development of players' performance characteristics, as players are not able to train full time for a period[34,35]. This illustrates the dynamical and somewhat unpredictable character of the performance development of youth basketball players towards the elite level in adulthood. To minimize the negative consequences of injuries it is highly important to ensure a successful outcome of the recovery process (i.e., return to pre-injury level of activity), in which psychosocial factors might be beneficial.

Objective and outline

The objective of this thesis is to gain insight into the performance development of talented youth male basketball players (aged 13-19) by adopting a multidimensional and longitudinal approach. The main focus of the thesis is on the multidimensional performance characteristics of basketball players in order to facilitate coaches, trainers, scouts and policy makers in the guidance of talented youth players towards the elite level of performance in adulthood.

Figure 1.2 provides an overview of the performance development of basketball players participating in the studies of this thesis (i.e., players who are part of the RTC). The y-axis shows the performance development of players. It is assumed that the performance level of players increases during their development (i.e., the performance level of U18 players is higher compared with U16 players). During the transition from one team to another, players get selected or deselected by coaches and trainers, as indicated by the dashed arrows. As it is well known that few athletes will achieve the top of their sport, due to the rising demands of players and the smaller window of opportunity over the years, the arrows indicating the transition into a higher age category become thinner and lighter[28].

The multidimensional and longitudinal approach applied in this thesis is displayed at the x-axis. It shows for each article (chapter 2-7) which of the multidimensional performance characteristics are investigated in which age category. Chapter 2 examines anthropometrical characteristics and the influence of maturity timing (age at PHV) in basketball players aged 13-16 years. In addition, this chapter focuses on the relation between maturity timing and anthropometrics on the one hand, and the specialization of players in one of the three playing positions on the other hand. In the next chapter (chapter 3), the repeated sprint ability of talented youth basketball players will be investigated. Multilevel modelling is used to evaluate the development of repeated sprint ability and to investigate potentially related factors in basketball players aged 14-19. Chapter 4 investigates the reproducibility and validity of a new basketball-specific test: the STARtest. The test aims to measure change-of-direction speed (performing the test without ball) and ball control (performing the test with ball). Chapter 5 continues research regarding the STARtest by examining the importance of ball control and self-regulatory skills in attaining the elite level. In addition, it investigates the development of, and association between those skills in basketball players (13-19 years) of different playing positions. The differences in positions will be further highlighted in chapter 6.

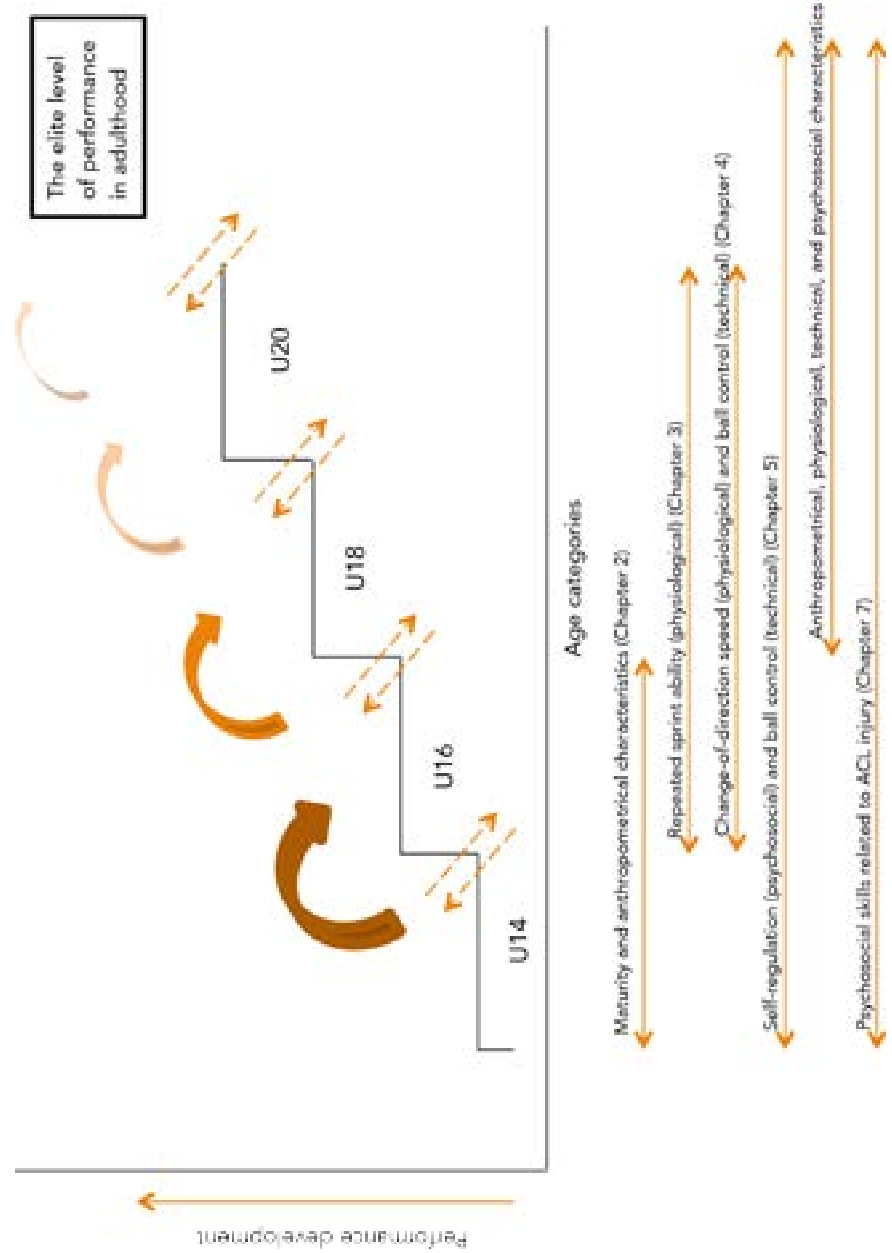

Figure 1.2: Overview of the performance development of talented youth basketball players in relation with the studies presented in this thesis.

1

This chapter focuses on the identification of position-related characteristics, and, in addition, on the individual differences in performance development of players (16-19 years) who managed to achieve the elite level of performance in adulthood. Furthermore, as injuries seem inevitably related to high performance and may have an influence on the performance development of athletes, the focus of this thesis shifts in chapter 7 towards the recovery of athletes with an ACL injury, i.e., a common severe injury in basketball. The literature review in this chapter provides an overview of psychosocial characteristics which might have an influence on the recovery of an ACL injury. Finally, chapter 8 presents the general discussion of the abovementioned studies and provides recommendations for basketball coaches, trainers, scouts, and policy makers related to the development of talented youth basketball players.

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Chapter 2

Role of maturity timing in selection procedures and in the specialization of playing positions in youth basketball

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R Vaeyens & C Visscher

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Abstract

This study investigated the role of maturity timing in selection procedures and in the specialization of playing positions in youth male basketball. Forty-three talented Dutch players (14.66 ± 1.09 years) participated in this study. Maturity timing (age at peak height velocity), anthropometrical, physiological, and technical characteristics were measured. Maturity timing and height of the basketball players were compared with a matched Dutch population. One-sample t-tests showed that basketball players were taller and experienced their peak height velocity at an earlier age compared to their peers, which indicates the relation between maturity timing and selection procedures. Multivariate analysis of variance (MANOVA) showed that guards experienced their peak height velocity at a later age compared to forwards and centers ($p < 0.01$). In addition, positional differences were found for height, sitting height, leg length, body mass, lean body mass, sprint, lower body explosive strength, and dribble ($p < 0.05$). Multivariate analysis of covariance (MANCOVA) (age and age at peak height velocity as covariate) showed only a significant difference regarding the technical characteristic dribbling ($p < 0.05$). Coaches and trainers should be aware of the interindividual differences between boys related to their maturity timing. Since technical characteristics appeared to be least influenced by maturity timing, it is recommended to focus more on technical characteristics rather than anthropometrical and physiological characteristics.

Keywords: talent identification, development, selection, position

Introduction

Basketball is a popular team sport worldwide among youth and adults. The national teams of the USA, Spain, and Argentina are the top three of the world ranking list of 2013[1]. The Dutch national team is at the bottom of this list, which means they are among the worst performing basketball teams in the world. This can partly be explained by the fact that only 2% of the children aged 10-14 in the Netherlands play basketball, indicating that the sport is fairly unpopular[2]. However, the poor performance of the Dutch national team is somewhat remarkable since height is one of the most important anthropometrical characteristics in basketball[3], and Dutch people are among the tallest people in the world[4]. With the basket located at 3.05 meter from the ground, being tall is an advantage to perform well. In youth basketball, the maturity timing of players influences their height. Maturation consists of structural and functional changes of the body during the development to maturity[5-7]. An often-used method to determine the maturity timing of players is estimating the age at which players show their peak height velocity. At this age, players experience their highest velocity of growth, and usually this occurs for boys at the age of 14[5,8]. However, the timing and tempo of maturity differ between individuals. In order to distinguish between players with respect to their maturation, they can be divided into early, average, or late mature groups. Earlier mature players experience their growth spurt and other body changes at a younger age compared to later mature players.

Research has shown that elite youth basketball players are significantly taller and experience their peak height velocity at an earlier age compared to sub-elite players[9,10]. In addition, anthropometrical differences have been found between the three different playing positions in youth basketball (guard, forward, and center). Guards are the smallest and experience their peak height velocity at a later age, whereas centers are the tallest and experience their peak height velocity at an earlier age[9,11,12]. These anthropometrical differences between level of performance (elite and sub-elite) and positions (guards, forwards, and centers) indicate the emphasis of maturity timing in youth basketball.

The aforementioned anthropometrical differences can also be found in adult basketball players[13-17]. However, in contrast to youth players, there is no longer an influence of maturity timing in adult basketball since these players are fully mature. In youth basketball, players in different phases of their maturity show large anthropometrical and physiological differences[18]. These differences can influence the interpretation of coaches and trainers regarding the performances of the basketball players. In order to improve the selection and specialization procedures of players, it is necessary to gain a better understanding of the role of maturity timing.

The aim of this study was to investigate the role of maturity timing in selection procedures and in the specialization of playing positions in youth basketball players. It was hypothesized that maturity timing has an influence on the anthropometrical characteristics of players and to a lesser extent to physiological and technical characteristics[9]. We further examined changes in playing position across several seasons.

Methods

Participants

Forty-three male basketball players (14.66 ± 1.09; age range 13-16) from a Dutch basketball academy participated in this study. This academy is a training center for talented youth basketball players in the northern part of the Netherlands. Players are selected or deselected by coaches and trainers each season, for one of the teams (U14, U16, or U18). The aim of the academy is to guide basketball players towards professionals in adulthood. The basketball players included in this study have playing experience of on average 5.33 ± 1.82 years. They train 14.82 ± 5.62 h per week and play on average 1.15 ± 0.92 matches per week. Players and parents/guardians gave written informed consent after being informed about the study procedure. The study was approved by the local research ethics committee and conformed to the recommendations of the Declaration of Helsinki.

Measurements

Anthropometrical characteristics. All anthropometrical measurements were performed by skilled testers. Height measurements for basketball players were done with a body length meter (Schinkel Medical, Nieuwegein, The Netherlands) on 0.01 centimeter accuracy, while players were standing against a wall. Sitting height was measured from the ground to the head, while players sat on the table with a straight back against the wall. By subtracting the height of this table from the measured height, sitting height was calculated. Leg length was calculated by subtracting the sitting height from the total height (i.e., height of players while they were standing against a wall). The plan of Frankfort was used to ensure all height measurements have been carried out the same way[19]. This means an upright posture of the head with the chin horizontally. In addition, body mass (kg) and fat percentage of players was measured with the Tanita Body Fat Monitor (TBF-300, Tokyo, Japan) while players were barefooted. The monitor controlled for other clothes (0.50 kg). Lean body mass (lbm) was calculated with the formula lbm = body mass – (body mass / 100) * fat percentage. The equation of Mirwald, Baxter-Jones, Bailey, and Beunen (2002) was used to determine the maturity offset of players (Maturity offset = −9.236 + 0.0002708 * leg length * sitting height) – (0.001663 * chronological age * leg length) + (0.007216 * chronological age * sitting height) + (0.02292 * body mass * height)[20]. Chronological age was determined by the formula: ((day of testing − day of birth) / 365) + ((month of testing − month of birth) / 12) + (year of testing − year of birth). Age at peak height velocity, which is the indicator of the maturity timing of players, was calculated by subtracting the maturity offset from the chronological age.

Basketball-specific characteristics. The Shuttle Sprint and Dribble Test is shown in figure 2.1 and contains three turns of 180°. Players had to perform three maximal sprints of 30 meter with 20 s rest in between. The test was performed without ball (sprint) and with ball (dribble). Time was measured with photocell gates (Eraton BV, Weert, The Netherlands). Outcome measures were 'sprint' (the best of three sprints), 'repeated sprint' (the total time of the three sprints), 'dribble' (the best of three dribble attempts), and 'repeated dribble' (the total time of the three dribble sessions) (all in seconds). The Shuttle Sprint and Dribble Test is a reliable and valid test to measure physiological characteristics[21].

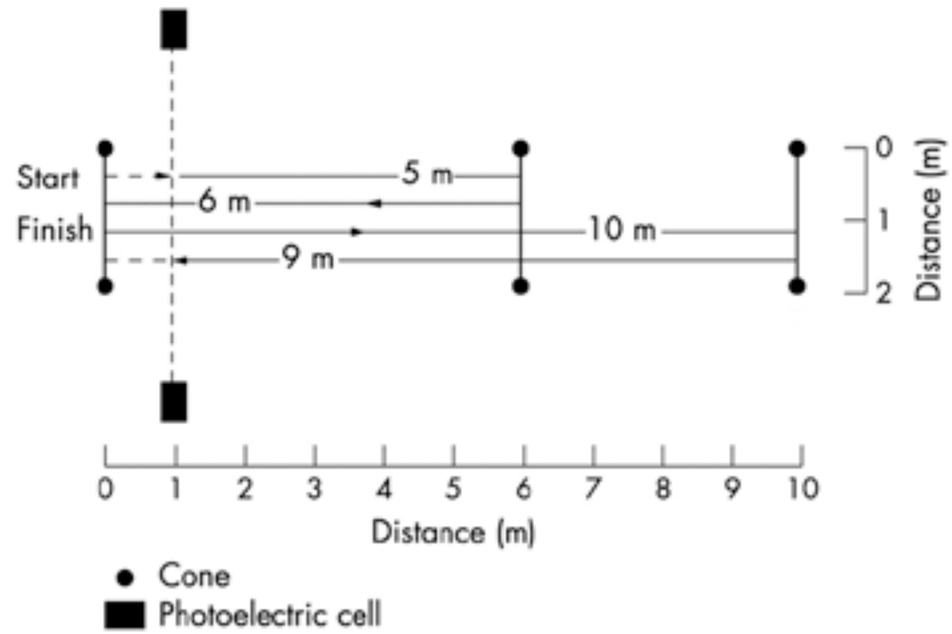

Figure 2.1: Course of the Shuttle Sprint and Dribble Test (adapted from Lemmink et al. 2004)[21].

The STARtest aims to measure change-of-direction speed (performing the test without ball) and ball control of players (performing the test with ball). The course of the STARtest is shown in figure 2.2. The test contains different forms of sprinting (forwards, backwards, and sideward slides) and changes of movements every 2 or 3 s, which makes this test a basketball-specific test. The test starts with a flying start between point AB after which players had to sprint forwards to point D, backwards to point E, side wards to point F, and forwards to points C and D. At this moment, players had to perform the same trajectory again on the other side of the field (G, H, C, D) and finally run forwards to point C and end between point AB. Time measurements started and stopped after passing line AB at the beginning and end of the test and were done by using a stopwatch. Outcome measures consisted of the time (s) when players perform the test without ball (change-of-direction speed) and with ball (ball control). Reproducibility (reliability and agreement) and validity of the STARtest was investigated in 52 basketball players performing a test-retest. The intraclass correlation coefficient (change-of-direction speed: 0.78; ball control: 0.80) and 95% confidence interval (change-of-direction speed: 0.64-0.87; ball control: 0.68-0.88) show good reliability. The agreement parameters standard error of measurement (change-of-direction speed: 0.33 s; ball control: 0.41 s), smallest detectable difference (change-of-direction speed: 0.92 s; ball control: 1.13 s), and coefficient of variation (change-of-direction speed: 1.77%; ball control: 2.03%) indicate good agreement between test and retest. In addition, it is shown that the STARtest is a valid test to measure performances of youth basketball players (discriminant validity was shown by significant differences in performances between age categories in the expected direction; construct validity was shown by sufficient correlations between Slalom Sprint and Dribble Test and the STARtest; sprint r = 0.74; dribble r = 0.60).

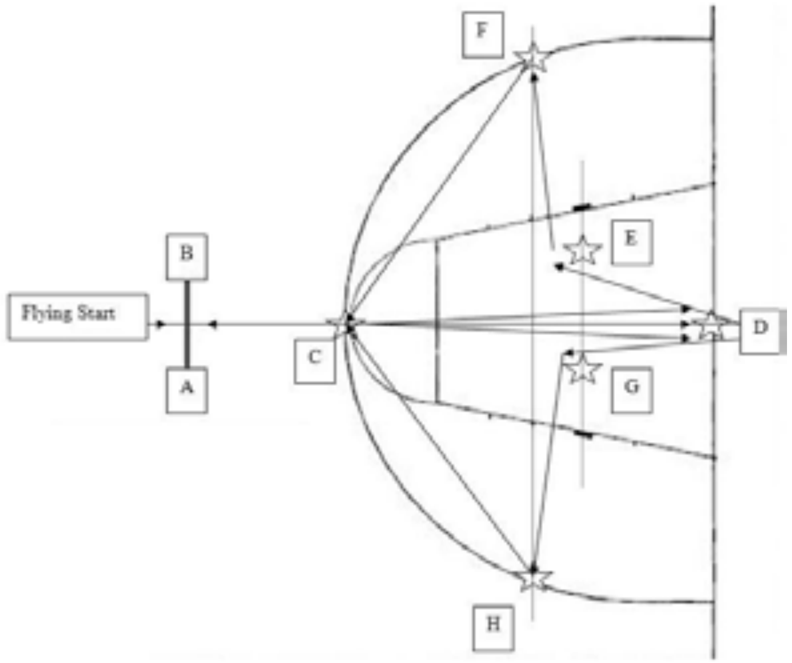

Figure 2.2: Course of the STARtest.

The vertical jump was measured using a yardstick device[22]. This device measures the maximal jump height to which players can push away sticks that are horizontally attached to a pole. Players were allowed to use a run-up and then jumped twice with their dominant leg, twice with their non-dominant leg, and twice with both legs. Sufficient rest between the jumps was ensured. Outcome measure is the lower body explosive strength of the dominant leg (m), since players mostly use this leg to jump during a game. Reliability of this test was determined by Gabbett et al. (2007)[22].

Players filled in a questionnaire about their playing position (guard, forward, or center). The playing position during the season before or after the season that is used for analysis in this study was used to investigate whether players changed position.

Procedures

All measurements have been carried in the afternoon at an indoor sports hall during the competitive season. Players were randomly divided into two groups; one group started with the anthropometrical measurements (height, sitting height, leg length, body mass, fat percentage, and lean body mass) and another group started with the physiological and technical field tests (Shuttle Sprint and Dribble Test, STARtest, and vertical jump test). During the physiological tests, sufficient rest in between was ensured. After about 1.5 h, the group of the physiological tests switched to the anthropometrical measurements and vice versa.

Statistical analysis

To investigate the role of maturity timing in selection procedures, anthropometrical data of the basketball players in this study were compared with a growth curve of a Dutch population, matched by age and gender[23]. One-sample t-tests were performed and effect sizes (Cohen's d) were calculated to investigate differences regarding the maturity timing and height for each age category. An effect size of 0.20 was considered small, around 0.50 moderate, and around or > 0.80 large[24]. To investigate the role of maturity timing in the specialization of playing positions, means and standard deviations for age (chronological age, age at peak height velocity), anthropometrical (height, sitting height, leg length, body mass, fat percentage, lean body mass), physiological (sprint, repeated sprint, change-of-direction speed, lower body explosive strength), and technical characteristics (dribble, repeated dribble, ball control) were calculated for guards, forwards, and centers. Multivariate analysis of variance (MANOVA) was performed to determine differences in age, age at peak height velocity, anthropometrical characteristics, physiological characteristics, and technical characteristics between playing positions. Effect sizes (Cohen's d) were calculated to interpret the differences in scores between the three playing positions. The aforementioned interpretations of effect sizes were used[24]. Furthermore, a multivariate analysis of covariance (MANCOVA) with chronological age and age at peak height velocity as covariate, and anthropometrical, physiological, and technical characteristics as dependent variables was performed. Bonferonni post hoc tests were used to specify the significant differences between positions. The level of significance for all statistical analyses was set at 0.05.

Results

Table 2.1 shows the height of basketball players in this study, the height of the average Dutch population matched by age and gender, the outcomes of the one-sample t-tests, and effect sizes. Although not significant, large effect sizes show that the 13- and 14-year-old players were taller compared to their Dutch peers ($d = 1.19$ and $d = 1.04$, respectively). For 15- and 16- year-old players, large effect sizes as well as significant differences in height were found between basketball players and their peers ($d = 2.05$; $p < 0.01$ and $d = 1.69$; $p = 0.02$, respectively). In addition, basketball players in this study experienced their peak height velocity at a significantly earlier age (13.06 ± 0.77) compared to boys aged 13-16 of the Dutch population (14 years) ($t(42) = -7.97$, $p < 0.01$).

Table 2.1: Height (m) of basketball players and the Dutch population[23], results of one-sample t-tests and effect sizes. Mean ± SD are shown.

Age (years)	Basketball players (m)	Dutch population (m)	t (df)	p	Effect size (Cohen's d)
13 (n = 10)	1.67 ± 0.08	1.62	1.73 (9)	0.11	1.19'
14 (n = 7)	1.77 ± 0.16	1.68	1.27 (6)	0.25	1.04'
15 (n = 14)	1.81 ± 0.06	1.75	3.69 (13)	< 0.01*	2.05'
16 (n = 12)	1.87 ± 0.10	1.79	2.81 (11)	0.02*	1.69'

Note: *significant difference at $p < 0.05$; ': large effect ($d > 0.80$).

Descriptive data of age, anthropometrical, physiological, and technical characteristics for the three different playing positions as well as effect sizes and results of the MANOVA are shown in table 2.2. MANOVA showed that chronological age was not significantly different between playing positions ($p > 0.05$). However, age at peak height velocity was significantly different between positions, with guards experiencing their peak height velocity at a later age compared to the other two positions ($p < 0.01$). Forwards ($p < 0.01$) and centers ($p = 0.02$) were significantly taller, had a higher sitting height ($p < 0.01$ and $p = 0.01$, respectively), were heavier ($p < 0.01$), and had a higher lean body mass ($p < 0.01$) compared to guards. In addition, forwards had a significant longer leg length compared to guards ($p = 0.01$). The physiological characteristics sprint (forwards faster than centers; $p = 0.04$) and lower body explosive strength (forwards higher than guards; $p = 0.02$) were significantly different between the three positions. Finally, guards had significantly better dribble performances (technical) compared to centers ($p < 0.01$).

Effect sizes indicated also the aforementioned differences between playing positions, but showed in addition a large effect size for the anthropometrical characteristics leg length and fat percentage (centers scored higher than guards), physiological characteristics sprint (guards faster than centers), repeated sprint (forwards faster than centers), and change-of-direction speed (guards and forwards faster than centers). In addition, a large effect size was shown for the technical characteristics dribble performances (forwards faster than centers), and repeated dribbling (guards faster than centers). Table 2.3 shows the results of the MANCOVA with chronological age and age at peak height velocity as covariate. It reveals that, after controlling for differences in age at peak height velocity between guards, forwards, and centers, there is only a significant main effect for the technical characteristic dribble ($p = 0.01$). Post hoc analysis showed that guards ($p = 0.02$) and forwards ($p = 0.049$) were faster than centers.

Information about position changes of players was available for 35 players. This data revealed that 11.4% (4 players) had a double position in the previous or next season (indicating that they were not specialized yet in one position). The majority of the players (77.1%; 27 players) did not change position, while 11.4% (4 players) did change position. Two players changed from forward to guard position (age 14 -> 15 and 15 -> 16), one player changed from center to forward (age 15 -> 16), and one player changed from forward to center position (age 16 -> 17).

Table 2.2: Age, anthropometrical, physiological, and technical characteristics of basketball players, according to their playing position as well as results of MANOVA and effect sizes. N=43.

	Mean ± SD			MANOVA		Effect sizes (Cohen's d)		
	Guards (n=14)	Forwards (n=19)	Centers (n=10)	F (df)	p	Guards vs. forwards	Guards vs. centers	Forwards vs. centers
Age								
Chronological age (years)	14.53 ± 1.25^{a}	14.81 ± 0.88^{a}	14.57 ± 1.29^{a}	0.30 (2,40)	0.74	0.26^{2}	0.03	0.22^{2}
Age at PHV (years)	13.73 ± 0.42^{a}	12.78 ± 0.68^{b}	12.47 ± 0.76^{b}	11.81 (2,40)	< 0.01	1.70^{1}	1.75^{1}	0.15
Anthropometrical characteristics								
Height (m)	1.70 ± 0.10^{a}	1.83 ± 0.08^{b}	1.83 ± 0.15^{b}	7.29 (2,40)	< 0.01	1.44^{1}	1.02^{1}	0.00
Sitting height (m)	0.86 ± 0.05^{a}	0.94 ± 0.05^{b}	0.94 ± 0.06^{b}	7.39 (2,40)	< 0.01	1.60^{1}	1.20^{1}	0.00
Leg length (m)	0.83 ± 0.05^{a}	0.89 ± 0.04^{b}	0.89 ± 0.06^{b}	5.18 (2,40)	0.01	1.33^{1}	0.90^{1}	0.00
Weight (kg)	54.39 ± 10.56^{a}	69.95 ± 13.09^{b}	71.73 ± 14.14^{b}	7.88 (2,40)	< 0.01	1.31^{1}	1.39^{1}	0.13
Fat percentage	8.75 ± 2.26^{a}	10.25 ± 4.42^{a}	11.73 ± 4.11^{a}	1.90 (2,40)	0.16	0.43^{2}	0.91^{1}	0.36^{2}
Lean body mass (kg)	49.63 ± 9.62^{a}	62.33 ± 9.14^{b}	63.13 ± 12.25^{b}	7.92 (2,40)	< 0.01	1.36^{1}	1.23^{1}	0.07
Physiological characteristics								
Sprint (s)	3.36 ± 0.45^{a}	3.36 ± 0.40^{a}	3.79 ± 0.42^{b}	3.94 (2,40)	0.03	0.00	0.99^{1}	1.05^{1}
Repeated sprint (s)	26.04 ± 1.53^{a}	25.95 ± 1.22^{a}	27.13 ± 1.36^{a}	2.97 (2,40)	0.06	0.07	0.79^{2}	0.95^{1}
Change of direction speed (s)	19.45 ± 1.15^{a}	19.38 ± 1.15^{a}	20.27 ± 0.75^{a}	2.52 (2,40)	0.09	0.06	0.84^{1}	0.92^{1}
Lower body explosive strength (m)	2.85 ± 0.23^{a}	3.06 ± 0.14^{b}	3.00 ± 0.25^{b}	4.55 (2,40)	0.02	1.10^{1}	0.62^{2}	0.30^{2}
Technical characteristics								
Dribble (s)	8.78 ± 0.51^{a}	8.97 ± 0.46^{a}	9.46 ± 0.60^{b}	5.38 (2,40)	< 0.01	0.39^{2}	1.22^{1}	0.92^{1}
Repeated dribble (s)	27.24 ± 1.38^{a}	28.15 ± 1.82^{a}	29.47 ± 2.15^{a}	2.95 (2,40)	0.06	0.29^{2}	0.94^{1}	0.66^{2}
Ball control (s)	21.26 ± 1.11^{a}	21.27 ± 1.45^{a}	22.21 ± 1.84^{a}	1.87 (2,40)	0.17	0.47^{2}	0.76^{2}	0.33^{2}

Note: ^{ab}: Within each row, means that do not share subscripts significantly differ from each other ($p < 0.05$); ^{3} small effect (d < 0.20), ^{2} moderate effect (d < 0.50), ^{1} large effect (d > 0.80).

Table 2.3: Results of MANCOVA with chronological age and age at PHV as covariate. Adjusted means (standard error) are shown. N=43.

	Guards	Forwards	Centers	MANCOVA	
	n = 14	n = 19	n = 10	[illegible]	[illegible]
[illegible]					
Height (m)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	0.91 ± [illegible]	0.91 ± [illegible]	[illegible]	[illegible]	[illegible]
Leg length	0.86 ± [illegible]	0.88 ± [illegible]	0.88 ± [illegible]	[illegible]	0.48
Weight (kg)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Fat percentage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]	[illegible]	[illegible]	9.41 ± [illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Discussion

The aim of this study was to investigate the role of maturity timing in selection procedures and in the specialization of playing positions in youth basketball. The results indicate that maturity timing has an influence on the selection procedure, since the basketball players that were selected for the basketball academy were taller and experienced their peak height velocity at an earlier age compared to their peers. These findings are in line with studies that showed a more advanced skeletal age in selected players compared to deselected players[25-27] and with a study of Santos Silva et al. (2013), which also demonstrated that basketball players were taller compared to their peers[3]. In addition, Hoare (2000) and Torres-Unda et al. (2013) showed that maturity parameters were positively related to the success of young basketball players[9,10]. All these results indicate that maturity timing is an important characteristic in youth basketball and that players who are more advanced in maturity are considered as better players than players who experience their maturity process at a later age. However, selecting players based on their maturity timing may be misleading and short-sighted for two reasons. First, the differences between players due to their maturity timing may disappear at the end of maturation[28-30]. For example, late mature players may be as tall as or even taller than early mature players at the end of their maturation[30]. It is therefore important for coaches and trainers to focus on the long-term development of players.

This was agreed upon by the trainers and the head of the Dutch basketball academy. In the future, they will more often use the players' predicted height (based on parents' height) instead of current height as a selection criteria (personal communication, 14 January 2014). Second, basketball is a multidimensional sport in which physiological, technical, tactical, and psychosocial characteristics also play an important role. Torres-Unda et al. (2013) showed for example that change-of-direction speed and ball handling are the most discriminating characteristics between elite and sub-elite basketball players, indicating other important characteristics basketball players should possess[10]. By selecting players mainly based on anthropometrical characteristics, coaches and trainers may overlook players that are talented, but experience their peak height velocity at a later age (i.e., false negatives) since the performances of these later maturing players are overwhelmed by the performances of earlier mature players. To avoid this problem, it is suggested to coaches and trainers to focus more on technical characteristics as selection criteria instead of anthropometrical characteristics.

The differences in age at peak height velocity between players of different positions found in this study suggest that maturity timing also influenced the specialization of playing positions. Coaches and trainers appear to be influenced by the maturity timing of players when choosing their playing position. The tallest players, who also experience their peak height velocity at an earlier age, are preferably placed on the center position, while the guard position is commonly played by players who experience their peak height velocity at a later age. These results are in line with other studies who showed that maturity timing and anthropometrical characteristics determine a player's position in basketball and other team sports[15,31,32]. However, specialization of playing positions based mainly on anthropometrical characteristics may lead to a non-optimal development of talented basketball players because, as mentioned earlier, later mature players may catch up with the earlier mature players[28,30].

After statistically controlling for differences in maturity timing between players, our results showed only a significant difference between positions for the dribble performances. This result suggests that technical characteristics seem to be less influenced by the maturity timing of players compared to anthropometrical and physiological characteristics, which supports our hypothesis and other research regarding basketball players and soccer players[33,34]. Although research has shown that technical characteristics can discriminate between elite and sub-elite athletes[35,36], the present study is unique since it also investigated technical differences between players of different positions. These technical characteristics seem to be very important in choosing the most appropriate position for players. When coaches ignore the influence of maturity timing in selecting players for a certain position, players may not get the opportunity to develop themselves at the position that best fits them. Therefore, when choosing the most appropriate position, coaches and trainers should consider the technical characteristics of players, rather than their anthropometrical or physiological characteristics. However, results of this study regarding maturity timing have to be interpreted cautiously due to the measurement method. The formula of Mirwald et al. (2002) was used to estimate the maturity offset of players[20]. Although this method is often used to estimate the maturity timing of athletes[8,37,38], recent research has shown that this method has some limitations[39]. This ensures that the results of this study regarding the maturity timing have to be interpreted cautiously.

To focus more closely on the specialization of playing positions, we investigated whether players changed position during two consecutive seasons. The results suggest that most players are specialized in one position at an early age and stay at this position during their development. According to Dezman et al. (2001), this early specialization is disadvantageous for the development of players since players should preferably start to specialize in one position from the age of 16[40]. Players younger than 16 years should train in a more versatile manner and practice at different positions. The results of several other studies also encourage players to participate in more sports at a younger age to develop fundamental motor skills, and to specialize from an age of 13-15 in one main sport[41-43]. Furthermore, one of the factors to success at senior level may be participating in multiple sports at a younger age and specializing in one main sport at a later age [6,41,44-46]. It is likely to assume that this principle can also be applied to the specialization for a certain position in basketball. Although players in this study did not often change position at a young age, it is recommended to train at various positions at early ages, and specialize in one position at a later age. In this way, players increase their chances of becoming an elite basketball player in adulthood since they are developed all-round and thus can eventually play at more than one position. Further research with more participants is recommended to clarify the (direction of) changes found in this study.

Conclusion

It is important for coaches and trainers to be aware of the differences in maturity timing between youth boys, since this can lead to large anthropometrical and physiological differences between them. Based on the results of this study, we recommend that coaches and trainers focus on technical instead of anthropometrical characteristics of players when selecting them for a selection team as well as for the specialization of a player's position. Rather than aiming at only short-term success, the long-term development of basketball players should be a priority. Furthermore, to increase a player's opportunity to eventually become a professional basketball player, it is suggested to train at different positions at a young age and specialize in one position at a later age (>16 years).

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Chapter 3

Development of repeated sprint ability in talented youth basketball players

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Abstract

Factors affecting repeated sprint ability (RSA) were evaluated in a mixed-longitudinal sample of 48 elite basketball players 14-19 years of age (16.1 ± 1.7 years). Players were observed on 6 occasions during the 2008-2009 and 2009-2010 seasons. Three following basketball-specific field tests were administered on each occasion: the shuttle sprint test for RSA, the vertical jump for lower body explosive strength (power), and the interval shuttle run test for interval endurance capacity. Height and weight were measured; body composition was estimated (percent fat, lean body mass). Multilevel modeling of RSA development curve was used with 32 players (16.0 ± 1.7 years) who had 2 or more observations. The 16 players (16.1 ± 1.8 years) measured on only 1 occasion were used as a control group to evaluate the appropriateness of the model. Age, lower body explosive strength, and interval endurance capacity significantly contributed to RSA ($p \le 0.05$). Repeated sprint ability improved with age from 14 to 17 years ($p \le 0.05$) and reached a plateau at 17-19 years. Predicted RSA did not significantly differ from measured RSA in the control group ($p \ge 0.05$). The results suggest a potentially important role for the training of lower body explosive strength and interval endurance capacity in the development of RSA among youth basketball players. Age-specific reference values for RSA of youth players may assist basketball coaches in setting appropriate goals for individual players.

Keywords: intermittent, high intensity, athletes, adolescence, interval

Introduction

Basketball is characterized by intermittent activity ranging from short bursts of high intensity to longer periods of moderate intensity and recovery[1,2]. The game includes frequent moderate to high intensity sprints (every 21 seconds on average) and changes in types of movements (walking, jogging, running, sprinting) every 2 or 3 seconds on average[1,3]. It is generally accepted that the repeated sprint ability (RSA) test captures the essence of game demands for basketball and other sports[4-6]. Given the perceived importance of RSA in basketball and other sports, data addressing the development of RSA in youth basketball players are relatively limited[7,8].

Elite basketball players differ from non-elite in speed and change-of-direction speed[9], which are key elements of RSA. However, information on the development of RSA in youth basketball players is relatively limited. Such information is potentially useful for coaches and trainers for player development and evaluation, individualizing training, and talent selection. Data on the development of RSA of talented youth basketball players can also serve as a reference for evaluation of players of different ages and talent levels with the goal of individualizing training and improving performance.

Anaerobic and aerobic energy systems influence RSA, i.e., predominantly anaerobic adenosine triphosphate (ATP) provision during sprinting and aerobic processes during recovery[6]. Anaerobic power can be measured by lower body explosive strength (vertical jump), which is highly relevant to basketball[3] and highly correlated with peak power in the Wingate test ($r = 0.86$)[10]. Aerobic power can be measured with a test of interval endurance capacity that indicates how well high intensity activities can be maintained. It also includes the ability to recover during low intensity activities[11]. The interval shuttle run test (ISRT) is a measure of the interval endurance capacity and is moderately to highly correlated with VO2max ($r = 0.77$). Given the interval nature of basketball, the ISRT is a useful measure of aerobic interval endurance capacity for the sport.

Changes in body size and composition with growth and maturation influence the anaerobic and aerobic performances[12-14] and may in turn influence RSA. Height and lean body mass (LBM), which are highly correlated, can potentially influence RSA. It has been suggested that height may negatively influence change-of-direction speed[15] and in turn negatively affect RSA[16], whereas LBM is mainly composed of muscle mass which influences anaerobic power[17] and positively affects RSA.

Repeated sprint ability improves, on average, with age in cross-sectional samples of youth. The changes are often attributed to age-related improvements in lower body explosive strength and interval endurance capacity[18,19]. Muscle mass, the vertical jump, and aerobic capacity have well-defined adolescent growth spurts; muscle mass and vertical jump have their growth spurts, on average, shortly after peak height velocity, although aerobic capacity (peak VO2) has its spurt close in time with peak height velocity[14].

This study evaluates the development of RSA and potentially related factors in a mixed-longitudinal sample of talented adolescent basketball players 14-19 years of age. It was hypothesized that chronological age, height, LBM, lower body explosive strength, and interval endurance capacity are primary determinants of the development of RSA in adolescent players. It was also hypothesized that the development of RSA in basketball players varies with age from mid-adolescence to late adolescence.

Methods

Experimental approach to the problem

Observations were made on youth players over 2 consecutive seasons. Measurements were taken before (September), during (January/March), and after (June) the 2008-2009 and 2009-2010 competitive seasons. Given the nature of sport (injury, drop out, changing interests, etc.), all players were not seen at each occasion. Number of measurement occasions for each player by age group is shown in table 3.1. The majority of players (n=32, 16.0 ± 1.7 years) had multiple measurements (3.6 ± 1.4), whereas the remainder (n=16, 16.1 ± 1.8 years) had a single observation. The sample of players with multiple observations was suitable for modeling RSA development curve. Players observed on only one occasion served as a control group to test the appropriateness of the model.

Table 3.1: Number of measurements per player by age group.

	Number of measurements						
Age category	1	2	3	4	5	6	Total
14	2	2	3	4	2	3	16
15	6	2	6	10	4	3	31
16	2	5	0	7	7	0	21
17	1	3	0	7	5	5	24
18	3	1	3	3	4	5	19
19	2	9	0	1	5	2	19
Total measurements	16	22	12	32	30	18	130
Number of players	16	11	4	5	6	3	48

Subjects

The sample included 48 select male basketball players from the Dutch Basketball Academy in the north of the Netherlands. There are a total of 5 youth basketball academies in the Netherlands. All players were considered talented based on performances relative to peers and potential for the professional level20. Players ranged from 14 to 19 years (16.1 ± 1.7 years) and were members of the selection team for 2.4 ± 1.1 years. As a group, the sample had 6.4 ± 2.1 years of experience in the sport. During the season, players completed 6.6 ± 2.3 practices and had 1.1 ± 0.3 games per week. All subjects (and/or parents when under 18) provided written informed consent. The study was approved by the ethics committee of the Medical Faculty of the University Medical Center Groningen, University of Groningen. Trainers and board of the basketball club also approved the study.

Procedures

Decimal age was recorded as the difference between date of birth and date of each observation. Age groups were defined with the whole year as the mid-point, i.e., 15 years = 14.50-15.49 years. Three following basketball-specific field tests were used: the shuttle sprint test (SST) for RSA, the vertical jump (VJ) for lower body explosive strength (power), and the ISRT for interval endurance. Height and weight were measured and body composition was estimated. All observations were made between 4 and 9 PM. Players were randomly divided into two groups. The first group started with anthropometry and body composition, whereas the second group started with the field tests. Sufficient rest between tests was ensured. Tests were performed at an indoor sports hall; measurements were carried out by the same individuals.

Shuttle Sprint Test. The SST is part of the shuttle sprint and dribble test and measures RSA[21]. Players performed 3 maximal 30 m shuttle sprints, with 20 seconds rest between sprints. Each sprint had three 180-degree angle turns (figure 3.1). Elapsed time was measured with photocell gates (Eraton BV, Weert, The Netherlands) placed at hip height. The outcome measure for RSA was the total time of the 3 * 30 m sprints (s). The test is reliable and valid[21-23].

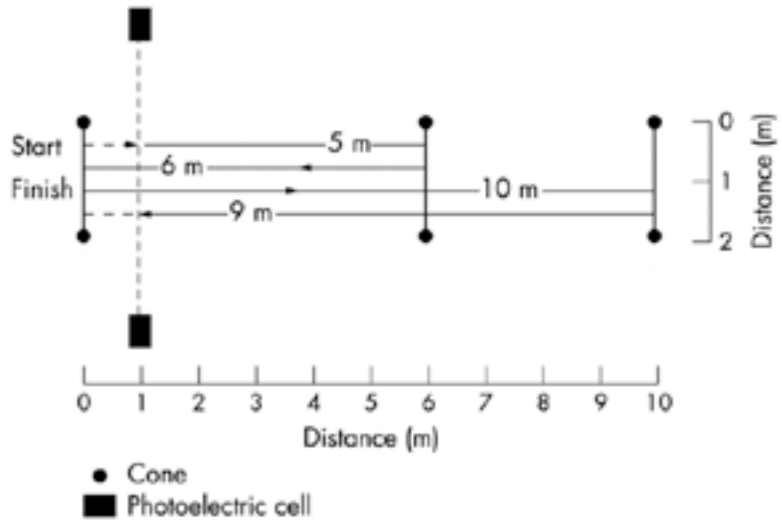

Figure 3.1: Course for the Shuttle Sprint Test (SST), adapted from Lemmink et al. (2004)[21].

Vertical Jump. The VJ was measured using a yardstick vertical jump device[24]. The device measures the height to which players could push away small sticks placed horizontally on a pole during a jump. Reaching height was subtracted from the height reached while jumping. The player had 6 attempts, 2 jumps with the dominant leg, 2 with the non-dominant leg, and 2 with both legs with sufficient rest between jumps. The highest attempt was retained for analysis. This VJ protocol has established reliability[24].

Interval Shuttle Run Test. The ISRT requires players to run back and forth on a 20 m course[11]. The pace and frequency of runs are regulated by a prerecorded CD with sound signals. Participants are required to be within the safe zone (3 m before the 20-m start line) before the next signal. The signals are recorded in such a way that running speed increases every 90 seconds; players run until exhaustion with a work-rest ratio of 2:1. The ISRT score was the total number of shuttles completed. The ISRT is a reliable and valid maximal field test for athletes in intermittent sports[11,23].

Anthropometry and body composition. Shoes and socks were removed. Height (cm) was measured with a tape fastened to the wall. Weight and percentage fat were assessed with a Tanita Body Fat Monitor, which has established reliability and validity[8]. LBM was estimated as (weight - [weight / 100 * percentage fat]).

Statistical analyses

Mean ± SD were calculated for all variables by age group. Pearson correlations among variables were calculated for the first observation and interpreted using the following guidelines: trivial, $r < 0.10$; small, $r = 0.10$-0.30; moderate, $r = 0.30$-0.50; large, $r = 0.50$-0.70; very large, $r = 0.70$-0.90; and nearly perfect, $r > 0.90$[25]. Because RSA is measured in time with less time implying a better performance, correlations related to RSA have been inverted to assure that for all correlations a positive sign means a better performance.

Multilevel modeling (MLwiN)[26] was used with the mixed-longitudinal subsample (n=32). Given the overlap in ages of the players, it was possible to estimate a 6-year development curve for RSA. Multilevel modeling permits use of measurements with variable spacing between observations[27]. The protocol provides insights of 2 sources of variance; within subject (level 1) and between subject (level 2). In the present analysis, hierarchy was defined as repeated measures (level 1) nested within the individual players (level 2). The first step in the multilevel modeling of RSA was to create a satisfactory variance structure using decimal age. Vertical jump, ISRT, height, and LBM were subsequently added. All variables were checked for interaction effects with age, and random slopes were considered. Multivariate analysis of variance was used to evaluate differences in RSA between age groups. Significance was set at 0.05.

The appropriateness of RSA regression model was investigated in the cross-sectional subsample of players with only 1 measurement (control group, n=16) using absolute reliability[28]. Repeated sprint ability was compared with predicted RSA based on the multilevel model. The difference between RSA and predicted RSA was calculated and tested against a mean difference of 0. Significance was set at 0.05.

Results

Descriptive statistics for all variables in the total mixed-longitudinal sample are summarized by age in table 3.2. Correlations among the basketball-specific field tests, body size, and estimated body composition at initial observation are shown in table 3.3. Repeated sprint ability was positive and at best moderately correlated with lower body explosive strength ($r = 0.35$). The correlation between RSA and interval endurance capacity was small and also positive ($r = 0.24$). These results thus show that a faster repeated sprint is associated with better performance on both the VJ and ISRT. The correlation between lower body explosive strength and interval endurance capacity was also moderate but positive ($r = 0.45$). Height was not related to RSA ($r = 0.01$) and LBM was not related to interval endurance capacity ($r = 0.01$). However, the correlation between LBM and RSA was small and positive ($r = 0.23$) and that between LBM and lower body explosive strength was moderate and positive ($r = 0.44$). As expected, height and LBM had a very large positive correlation ($r = 0.86$). The correlation between height and explosive strength was positive and moderate ($r = 0.39$), whereas that between height and interval endurance capacity was small and negative ($r = -0.11$).

Table 3.2: Mean (SD) for basketball-specific functional tests, body size and estimated body composition for the total mixed-longitudinal sample of youth basketball players by age group (n=48; number of measurements=130).

Cohort (yr)	n	Age (y)	SST* (s)	VJ (cm)	ISRT (20m runs)	Height (cm)	Weight (kg)	Percentage fat (%)	LBM (kg)
14	16	14.09	26.09	70.50	96.94	176.37	62.03	8.61	56.63
		(0.27)	(0.94)	(0.01)	(17.48)	(0.13)	(14.27)	(2.34)	(12.66)
15	31	14.96	25.69	75.81	99.90	183.65	70.22	10.19	63.14
		(0.29)	(1.04)	(0.09)	(19.59)	(0.07)	(11.30)	(3.08)	(8.62)
16	21	15.96	25.97	81.00	104.24	188.75	75.79	11.77	66.75
		(0.27)	(1.21)	(0.10)	(19.48)	(0.07)	(11.92)	(4.45)	(7.32)
17	24	16.99	25.13	84.67	118.00	190.36	77.62	8.93	70.70
		(0.33)	(0.97)	(0.07)	(15.09)	(0.05)	(7.55)	(3.00)	(7.49)
18	19	18.03	25.14	86.42	115.05	188.92	78.79	6.17	73.87
		(0.27)	(1.02)	(0.07)	(22.03)	(0.11)	(8.64)	(1.67)	(7.52)
19	19	18.95	24.82	87.47	115.26	189.06	82.87	7.90	76.26
		(0.26)	(1.04)	(0.05)	(15.57)	(0.09)	(7.65)	(1.94)	(6.52)

Note: *Lower score indicates a better performance; SST = Shuttle Sprint Test; VJ = Vertical Jump; ISRT = Interval Shuttle Run Test; LBM = Lean Body Mass.

Table 3.3: Correlations between repeated sprint ability (RSA), Lower body explosive strength, Interval endurance capacity, Height, and Lean Body Mass (LBM) in total sample of basketball players at the first observation (n=48)

	RSA	Lower body explosive strength	Interval endurance capacity	Height	LBM
RSA	1.00	[illegible]	[illegible]	[illegible]	[illegible]
Lower body explosive strength		1.00	[illegible]	[illegible]	[illegible]
Interval endurance capacity			1.00	[illegible]	[illegible]
Height				1.00	0.88**
LBM					1.00

[illegible]

The model for RSA is summarized in table 3.4. Age ($x^2[1] = 19.78$, $p \leq 0.05$) significantly improved the model. Age² was added second but did not improve the model (x^2 [1] = 1.71, $p \geq 0.05$). Subsequently, lower body explosive strength (x^2 [1] = 10.87, $p \leq 0.05$) and interval endurance capacity (x^2 [1] = 4.89, $p \leq 0.05$) were added and both significantly improved the model. The addition of height and LBM did not significantly improve the model ($p \geq 0.05$). All variables were also tested for interaction with age, but no interactions improved the model ($p \geq 0.05$). Random slopes also did not improve the model fit ($p \geq 0.05$).

Table 3.4: Multilevel model for the Shuttle Sprint Test (SST) in talented youth basketball players.

Fixed Effects	Coefficient	Standard Error	p
Constant	[illegible]	1.180	< 0.05
Age	[illegible]	0.078	< 0.05
Vertical Jump Test	[illegible]	[illegible]	< 0.05
Interval Shuttle Run Test	-0.012	0.002	< 0.05
Random Effects	**Variance**	**Standard Error**	
Residual variance at level 1	[illegible]	0.082	
Between players (level 2)	0.255	[illegible]	
Deviance	264.4		
Deviance change from null model	34.78		
p < 0.05			

The model suggests that better RSA performances (i.e., lower score in seconds on the SST) are achieved by older players with better lower body explosive strength and interval endurance capacity. The residual intercept (level 1) indicates that within-player variance is 64% (0.525/[0.299 + 0.525] * 100). Between-player variance (level 2) is 36% (0.299/[0.299 + 0.525]). Coefficients for age, lower body explosive strength, and interval endurance capacity are unstandardized. Their effects can be interpreted as follows: adding 1 year of age results in the same improvement as increasing in VJ by 4.2 cm (0.161 / 3.816 * 100) or increasing in ISRT by 13.4 trajectories (20 m runs) (0.161 / 0.012).

Figure 3.2 shows predicted RSA scores. Performance improves (times decrease) in a linear and significant manner between 14 and 17 years ($p < 0.05$) and then seem to plateau as differences between 17 and 19 are not significant ($p > 0.05$). Overall, RSA performance improves (times decrease), on average, by 1.58 seconds from 14 to 19 years, but estimated mean improvement in RSA is -0.41 s per year between 14 and 17 years compared to only -0.17 s per year between 17 and 19 years.

The test for absolute reliability indicates no significant difference between actual RSA and predicted RSA based on the above model applied to the control group ($t = 1.06$; $df = 16$; $p > 0.05$). This result highlights the appropriateness of the multilevel model.

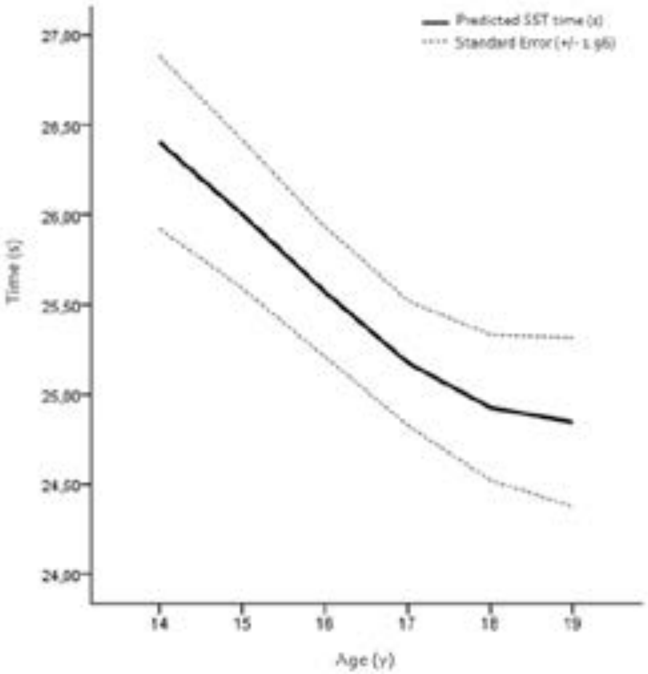

Figure 3.2: Development of the predicted scores on the Shuttle Sprint Test (SST) with the Standard Error of the prediction from 14 to 19 years in talented youth basketball players. Significant differences ($p < 0.05$): age 14 vs. ages 16-19, age 15 vs. ages 16-19, age 16 vs. ages 14-15 and 18-19, age 17 vs. ages 14-15, age 18 vs. ages 14-16, age 19 vs. ages 14-16.

Discussion

The present study considered the development of RSA and related growth and functional parameters in a mixed-longitudinal sample of elite youth basketball players 14-19 years of age. Repeated sprint ability is seen as an important characteristic for youth basketball players to become successful[9]. The positive correlation between RSA and lower body explosive strength indicates that a better lower body explosive strength is related to a better RSA. This is in line with a recent study of Stojanovic et al. (2012)[29], which shows that counter movement jump (also measuring lower body explosive strength) is a predictor of RSA in basketball players. The correlation between RSA and interval endurance capacity was also positive, indicating that a higher interval endurance capacity is related to a better RSA. Because the SST, VJ, and ISRT tests are sufficiently reliable[11,21,24], it is likely that a learning effect was minimal; moreover, basketball training and monitoring protocols do not require these tests on a regular basis.

Age, lower body explosive strength, and interval endurance capacity were significant predictors of RSA, whereas height and estimated body composition were not significant predictors in the multilevel analysis. The utility of lower body explosive strength and interval endurance capacity as significant predictors of RSA implies that both functions should be essential parts of training programs for youth players in an effort to improve RSA, which is recognized as an essential component of basketball performance[1,30].

Repeated sprint ability also improved, on average, with age from 14 to 19, but the major improvement occurred between 14 to 17 years. This may contribute to the larger within-player variance (64%) compared with between-player variance (36%).The difference in variances implies that improvement in RSA within individual players is greater than improvements between players. This in turn is related to individual differences in growth and maturation and also functional development[31]. Potential individual differences in the timing of adolescent growth in size, composition and functional capacities highlight a need for further study of RSA among youth athletes. This study found no relation between height and RSA. Repeated sprint ability was measured with the SST in which players had to perform a trajectory with turns of 180-degree angle (i.e., change-of-direction speed). Therefore, smaller players might benefit from their height in this test. The negative and positive effects of height may neutralize each other, suggesting no distinct relation between height and RSA. Another explanation might be the homogeneity concerning the height of players. Most players have probably stopped growing in height after the age of 15 years.

Performances in lower body explosive strength, interval endurance capacity, and motor skills in general improve during male adolescence[14,32-34]. On average, adolescent gains in static strength and lower body explosive strength (vertical jump) reach peak velocity shortly after peak height velocity (PHV) of the growth spurt, whereas aerobic power has its peak velocity at the same time as peak height velocity. Thus rapid improvements from 14 years may be explained, in part, by normal variation in the adolescent growth spurt[35]. This is suggested in the observations of Mendez-Villanueva et al. (2011)[36] who noted a reduction of age-related differences in RSA when predicted age at PHV was statistically controlled in soccer players 11-18 years of age. Though interesting, the results for soccer players were likely influenced by limitations using predicted age at PHV. The predictions are influenced by chronological age, i.e., the younger the boy, the earlier the age at PHV; and the older the boys, the later the age at PHV[37].

The large improvement in RSA from 14 to 17 years may reflect in part the adolescent spurt in lean tissue and continued growth in muscle mass into later adolescence[14]. This would be reflected in greater muscle cross-sectional area which increases exponentially in males until 17 years[38]. The relative influence of growth and maturation is less with increasing age in later adolescence, i.e., in players 17 to 19 years old. At these ages, many youth basketball players are nearing skeletal maturity or are already mature[39]. As such, RSA, lower body explosive strength, and interval endurance capacity improve less than at younger ages.

Although the model could be improved with even more measurement occasions per player over age, by evaluating the model, it can be concluded that single predictive characteristics are significant contributors. In addition, the basketball specific field tests give information about characteristics that are highly relevant for basketball (lower body explosive strength and interval endurance). Consistent with the primary hypothesis of the study, age and two functional capacities, lower body explosive strength and interval endurance capacity, are significant predictors of RSA in adolescent basketball players 14-19 years. Repeated sprint ability develops most rapidly from 14 to 17 years and tends to reach a plateau from 17 to 19 years. Application of the model to the control group (players tested on only 1 occasion) illustrates its predictive utility.

Practical applications

Repeated sprint ability is viewed as an important characteristic for success among talented youth basketball players. As such, it would serve a coach well to be aware of RSA of the players. Repeated sprint ability can be efficiently measured with the Shuttle Sprint Test so that periodic testing of players (e.g., twice per season) would assist in the coaching process. The developmental curve for RSA in this sample of elite youth basketball players can serve as an appropriate reference for the comparison of youth basketball players of the same age. The developmental curve, however, is based on the performances of Dutch basketball players. It is recommended that coaches and trainers develop reference curves for their own players to provide guidance for individual players. Perhaps more important, relationships between RSA and game performances should be addressed. These may serve as a valuable coaching tool with young players. Reference values from the present study are based on select players. As such, they may also be useful for talent identification and selection. Nevertheless, no selection protocol is perfect. Application requires caution and sensitivity to the needs of the young athletes.

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Chapter 4

Reproducibility and validity of the STARtest; a test to monitor the change-of-direction speed and ball control of youth basketball players

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Abstract

The current study investigated the reproducibility and validity of the STARtest. This test measures change-of-direction speed (performing the test without ball) and ball control (performing the test with ball). Youth basketball players (male and female; N=52; 16.25 ± 1.48 years) performed the STARtest without ball and with ball twice (both conditions once during test and once during retest), with two-four weeks between test and retest. No significant differences between test and retest were found ($p > 0.05$). The STARtest was found highly reliable (intraclass correlation coefficient [ICC] (95% confidence interval) change-of-direction speed = 0.78 (0.64-0.87) and ball control = 0.80 (0.68-0.88)). There was sufficient agreement between test and retest for change-of-direction speed and ball control (standard error of measurement [SEM] 0.33 s and 0.41 s, smallest detectable difference [SDD] 0.92 s and 1.13 s, and coefficient of variation [CV] 1.77% and 2.05%, respectively). Multivariate Analysis of Variance (MANOVA) showed that 18-19-year-old players were faster in change-of-direction speed in comparison to 14-15-year-old players ($p = 0.046$). Both 16-17-year-old ($p = 0.04$) and 18-19-year-old ($p = 0.03$) players had better ball control compared to 14-15-year-old players. The slalom sprint and dribble test was used as the criterion standard for measuring construct validity. Pearson's correlation between the slalom sprint test and STARtest measuring change-of-direction speed was 0.74 (very large), and between the slalom dribble test and STARtest measuring ball control 0.60 (large). In conclusion, the STARtest is a reproducible and valid test and it is recommended to coaches and trainers to use the STARtest for monitoring the individual change-of-direction speed and ball control of youth basketball players.

Keywords: reliability, performance monitor, talent identification, talent development, basketball-specific

Introduction

Basketball, like many other team sports, involves short, intense and repeated episodes of activity[1-3]. The game has an intermittent pattern with players changing their actions (e.g., sprinting, dribbling, jumping) every two or three seconds[4]. Sprinting and dribbling are not limited to forward and backward directions, since 30% of the movements occur in a lateral direction. Not surprisingly, change of direction with the whole body, i.e., change-of-direction speed, is an important aspect for basketball players[5]. Due to this complex nature of the game, physiological and technical characteristics are highly important for youth basketball players[6,7].

Researchers have consistently identified change-of-direction speed as one of the most important skills to determine the performance level of basketball players[4,8-10]. In addition, ball control is also a discriminative skill between elite and non-elite basketball players[10]. It is therefore important to gain more insight into these skills and to develop a test that is able to measure both change-of-direction speed as well as ball control.

Given the importance of using sport-specific tests[11], coaches and trainers should use a test that includes the aforementioned basketball-specific actions to measure the change-of-direction speed and ball control of youth basketball players. The STARtest is such a test and is developed by high qualified coaches and trainers of talented youth basketball players. The STARtest has been used in practice for more than a decade to assess and monitor the change-of-direction speed and ball control of youth basketball players in a longitudinal way. Acceleration, change of direction, and speed are combined in this test to make the test as basketball-specific as possible.

For talent identification and development purposes within sports, it is important to monitor the current performance level, as well as the development of youth athletes[12,13]. Athletes who are the best during their junior years will not necessarily remain the best athletes in adulthood, due to effects of training and maturation[e.g., 12,14]. Moreover, it is very hard to predict which athletes will ultimately attain the elite level of performance and which athletes will attain a sub- or non-elite level[15]. Recent research, for example, has shown that coaches and trainers of youth basketball players have some difficulties in predicting the future performance level of their players[16]. For these reasons, it might be helpful for coaches and trainers to use a reproducible and valid test that easily measures important performance characteristics of youth basketball players.

Therefore, the aim of this study was to investigate the reproducibility and validity of the STARtest, which is a test that is already being used in practice by high qualified coaches and trainers of youth basketball players. The reproducibility of a test indicates whether a test is able to give similar results in repeated measurements of the same persons. To examine the reproducibility of the STARtest, reliability and agreement parameters need to be assessed[17]. In addition, the STARtest can be considered valid when the test is able to discriminate between the performances of players of different age categories (discriminant validity), and when the test contains features that are typical for basketball (construct validity).

Methods

Participants

Participants were recruited from one of the national talent development programs for youth basketball players in the Netherlands. The sample was composed of 52 adolescent players (males: n=40, 16.38 ± 1.48 years; females: n=12, 15.83 ± 1.47 years) who had played competitive basketball for 5.95 ± 2.29 years, and were training 13.08 ± 3.83 hours per week. The age of players was defined as follows: a player aged 13.50-14.49 was considered as 14 years old, 14.50-15.49 as 15 years old and so on. For validity purposes, age was divided into three categories: 14-15 years, 16-17 years, and 18-19 years. The mean age of all participants was 16.25 ± 1.48 years (N=52). After being informed about the study procedures, the parents/guardians and the participants gave their written consent to participate. This study was approved by the local ethics committee.

Measurements

STARtest

The STARtest was designed by high qualified basketball coaches and trainers with the aim to develop a test that measures change-of-direction speed (performing the STARtest without ball) and ball control (performing the STARtest with ball) in a basketball-specific setting. The trajectory of the STARtest is shown in figure 4.1. The path was set out on one half of a regular sized basketball court (FIBA rules: length = 28 m; width = 15 m). The trajectory uses the lines of the 3-point area, with a radius of 6.25 m. The STARtest starts out with a flying start through line AB, after which the following types of sprinting (performing the test without ball) or dribbling (performing the test with ball) have to be performed:

- Forwards to point D
- Backwards to point E
- Lateral shuffling to point F
- Forwards to point C
- Forwards to point D
- Backwards to point G
- Lateral shuffling to point H
- Forwards to point C
- Forwards to point D
- Forwards to point AB

Time measurements started and stopped after passing line AB at the beginning and end of the test, and were performed by electronic timing gates (Eraton BV, Weert, The Netherlands). Outcome measure was the time in seconds that players needed to perform the STARtest without ball and with ball.

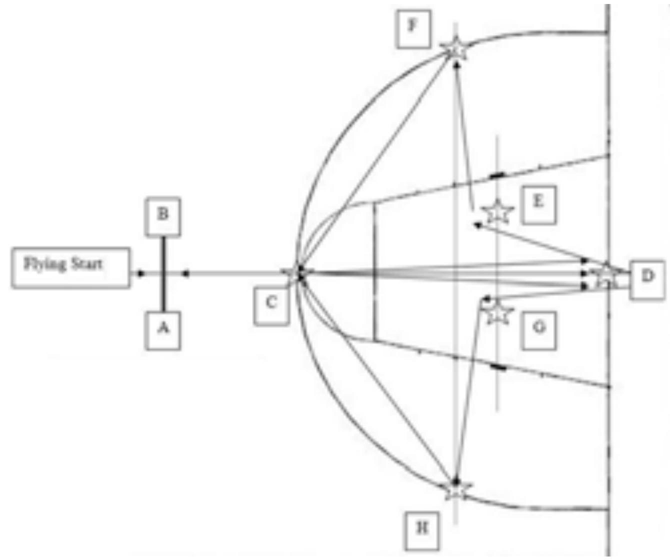

Figure 4.1: Course of the STARtest.

Slalom Sprint and Dribble Test

The slalom sprint and dribble test was used as the criterion standard for measuring construct validity, since this test also measures a form of change-of-direction speed (performing the test without ball) as well as ball control (performing the test with ball). The slalom sprint and dribble test is a field test in which players have to sprint or dribble forwards around twelve cones in a zigzag pattern, as shown in figure 4.2[18]. Time measurement started at point A, and ended when players finished at point B. Time was tracked by an observer using a stopwatch. Outcome measures consisted of the time players needed to perform the slalom test without ball (s) and with ball (s). Besides the indication of a good reliability (without ball: Intraclass Correlation Coefficient [ICC] = 0.91; with ball: ICC = 0.79) and validity (i.e., discriminative between level of performance) for hockey players and soccer players[18-21], the test can also discriminate between the dribble performances of different playing positions of young basketball players (guards < forwards < centers)[22].

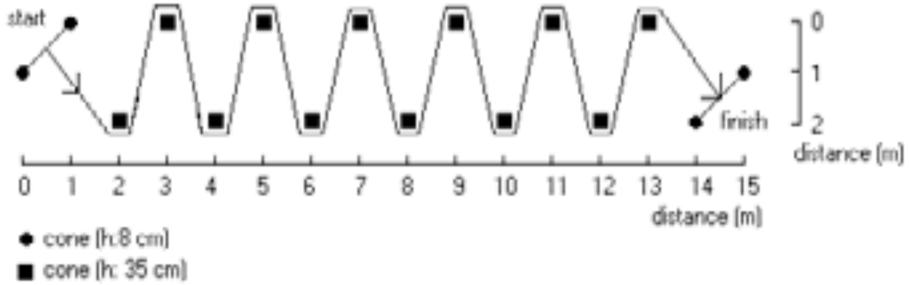

Figure 4.2: Course of the Slalom Sprint and Dribble Test[18].

Procedures

The protocol of this study consisted of two test days (i.e., test and retest) during the competitive season. Both test and retest were performed on the same day of the week, with two till four weeks between test and retest. Within these weeks, normal training sessions were performed. During the first test day, all participants performed the STARtest and the slalom test once without ball and once with ball (to measure change-of-direction speed and ball control, respectively). Sufficient rest between the measurements (at least five minutes) was ensured. Regarding the STARtest, players walked the trajectory of this test once beforehand, to ensure the directions of the test were evident. Players were instructed to complete the trajectory as fast as possible. During the test and retest of the STARtest, one of the observers provided verbal instructions about the directions and type of movements in order to prevent erroneous movements. The slalom sprint and dribble test applied the same protocol as the STARtest, that is, performing the test once without ball, and once while dribbling with the ball, with sufficient rest in between. However, the basketball players did not walk the trajectory of the slalom sprint and dribble test in advance, since the course of this test was more obvious (figure 4.2). During the second test day (retest), only the STARtest was executed with the same protocol as during the first test day. All players were familiar with the STARtest as well as the slalom sprint and dribble test.

Statistical Analysis

Data was analyzed using IBM SPSS Statistics software (version 20.0; Inc., Chicago, Illinois, United States of America). Reproducibility was investigated by examining reliability and agreement parameters[17]. For the reliability of the STARtest, the ICC was calculated with adoption of a two-way mixed model (single measure)[23]. An ICC < 0.40 was considered as poor, 0.40-0.70 as fair, 0.70-0.90 as good, and > 0.90 as excellent[24]. The agreement between the test and retest of the STARtest was investigated by calculating the standard error of measurement (SEM), the smallest detectable difference (SDD), and the coefficient of variation (CV) as shown in equations 1, 2, and 3, respectively[17,23,25]. Furthermore, 95% limits of agreement (LOA) were calculated and Bland-Altman plots were illustrated[26].

Equation 1: $SEM = SD * \sqrt{(1 - ICC)}$

Equation 2: $SDD = 1.96 * \sqrt{2} * SEM$

Equation 3: $CV = (SEM / Mean) * 100\%$

Two types of validity were investigated. First, a multivariate analysis of variance (MANOVA) was performed to examine discriminant validity among male basketball players (n=40) of different age categories (i.e., 14-15 years vs 16-17 years vs 18-19 years). We only analyzed the scores of the male participants, since we expected gender to influence the results. The scores of change-of-direction speed and ball control of the first test day were entered as dependent variables and age category was entered as fixed factor. Effect sizes were calculated to interpret the differences between age categories. An effect size < 0.20 was considered as small, around 0.50 as moderate, and around or > 0.80 as large[27]. Second, construct validity was investigated by examining the Pearson's correlation between the STARtest (performances of the first test day) and the slalom sprint and dribble test for all players (N=52). A Pearson's correlation of <0.10 was considered as trivial, 0.10-0.30 as small, 0.30-0.50 as moderate, 0.50-0.70 as large, 0.70-0.90 as very large and > 0.90 as nearly perfect[28]. Level of significance for all analyses was 0.05.

Results

Table 4.1 summarizes the scores of the STARtest obtained during the test and retest, as well as the reproducibility parameters (i.e., reliability and agreement parameters). Results showed that there were no significant differences between test and retest, neither for the change-of-direction speed ($t(51) = 0.90$, $p = 0.37$), nor for the ball control of players ($t(51) = 0.76$, $p = 0.45$). Bland-Altman plots are shown in Figure 4.3 and 4.4 for the STARtest without ball (change-of-direction speed) and STARtest with ball (ball control), respectively. The STARtest without ball has three outliers (two positive and one negative), whereas the STARtest with ball shows three positive and one negative outlier.

Table 4.1: Descriptive statistics (mean ± SD) and reproducibility parameters of the STARtest (N=52).

		Change-of-direction speed	Ball control
Test (s)		18.68 ± 0.96	20.02 ± 1.47
Retest (s)		18.60 ± 1.11	19.92 ± 1.50
Mean of both tests (s)		18.64 ± 0.98	19.97 ± 1.47
Mean difference test-retest (s)		0.01 ± 0.70	-0.01 ± 0.91
ICC		0.78	0.83
	95% CI	0.64-0.87	0.68-0.88
SEM (s)		0.33	0.41
SDD (s)		0.92	1.13
CV (%)		1.77	2.05
LOA	Lower	-1.36	-1.80
	Upper	1.38	1.77

Note: ICC = intraclass correlation coefficient; CI = confidence interval; SEM = standard error of measurement; SDD = smallest detectable difference; CV = coefficient of variation; LOA = limits of agreement.

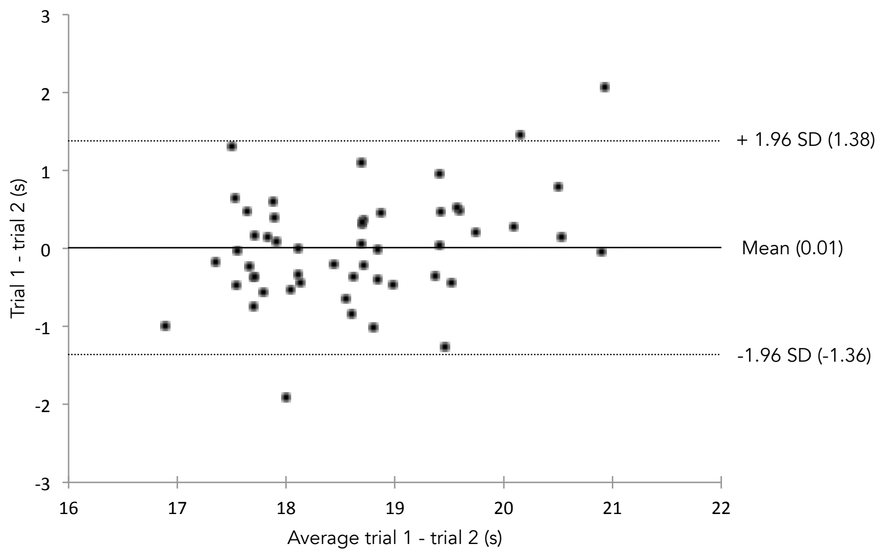

Figure 4.3: Bland-Altman plot – STARtest without ball (change-of-direction speed).

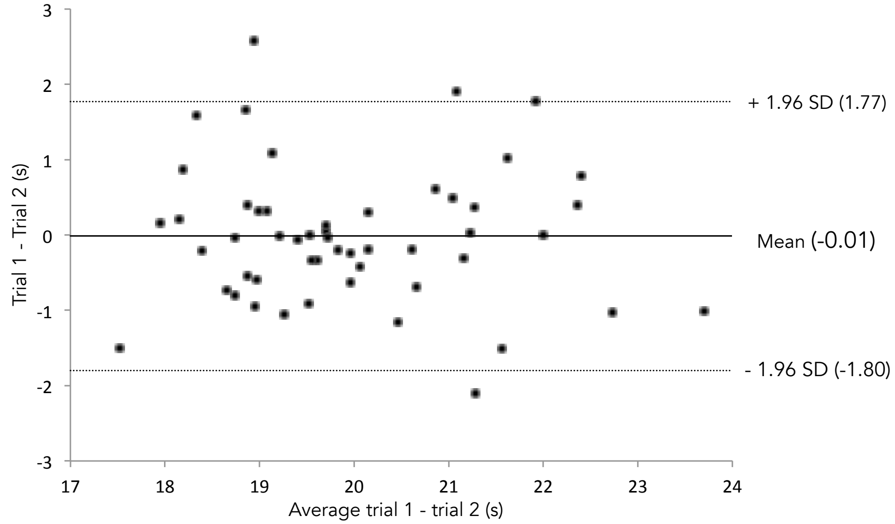

Figure 4.4: Bland-Altman plot – STARtest with ball (ball control).

For validity purposes, descriptive statistics of male basketball players by age categories are shown in table 4.2. MANOVA showed a main effect for age categories regarding change-of-direction speed (F(2,37) = 4.09, p = 0.03). Post-hoc results demonstrated that 18-19-year-old players were significantly faster on the STARtest without ball (change-of-direction speed) compared to 14-15-year-old players (p = 0.046). The differences between the ages 14-15 and 16-17, and between 16-17 and 18-19 were not significant, although the effect sizes were large and moderate, respectively. In both cases, the older group players were faster compared to the younger group. Regarding the STARtest with ball (ball control) (F(2,37) = 4.98, p = 0.01), both 16-17 (p = 0.04) and 18-19-year-old players (p = 0.03) were significantly faster compared to 14-15-year-old players. Moreover, a moderate effect size was found for 16-17 and 18-19-year-old players, again with the older players being faster.

Mean score of the slalom test without ball was 14.10 ± 0.84 s and of the slalom test with ball was 14.91 ± 1.09 s. The significant correlations between the Slalom test without ball and STARtest without ball (r = 0.74), and between the Slalom test with ball and STARtest with ball (r = 0.60) were considered as very large and large, respectively.

Table 4.2: Descriptive statistics and effect sizes of the STARtest without ball (change-of-direction speed) and STARtest with ball (ball control) of male players according to their age categories (n=40).

	Mean ± SD			Effect size (Cohen's d)		
	14-15 year (n=14)	16-17 year (n=20)	18-19 year (n=6)	14-15 vs. 16-17 year	14-15 vs. 18-19 year	16-17 vs. 18-19 year
Change-of-direction speed (s)	19.06 ± 1.02	18.33 ± 0.80	18.00 ± 0.74*	0.78*	1.15*	0.42*
Ball control (s)	20.48 ± 1.2[illegible]	19.45 ± 1.06*	19.03 ± 0.94*	0.89*	1.31*	0.42*

Note: [illegible]

Discussion

The current study examined the reproducibility and validity of the STARtest. This test is a basketball-specific test with the aim to assess and monitor the performances of youth basketball players. The results of this study showed that the STARtest is a reproducible and valid test to measure and monitor change-of-direction speed and ball control of youth basketball players.

Based on the ICC for both the STARtest without ball (change-of-direction speed) and STARtest with ball (ball control) this test was deemed sufficiently reliable. The interpretation of the agreement parameters SEM and LOA is dependent on the context[29]. Related to the STARtest, the SEM values were considered to be small and the LOA values to be narrow, which indicate good agreement between test and retest. The CV, which represents the relative error compared to the mean, was similar to the results of other research concerning basketball tests, indicating sufficient agreement between test and retest[30,31].

Validity analysis showed that older players were significantly faster compared to younger players on both the STARtest without ball (change-of-direction speed) as well as the STARtest with ball (ball control). This result confirms our hypothesis and is in line with other research that showed an improvement in speed with increasing age to perform tests that measure change-of-direction speed and ball control[32-34]. In addition, there was a very large correlation between the STARtest without ball and the slalom test without ball (r = 0.74), and a large correlation between the STARtest with ball (ball control) and the slalom test with ball (r = 0.60). These results support our hypothesis, since we expected a moderate to strong, positive correlation between the tests, as both tests measure partly the same aspects (e.g., a form of change-of-direction speed and ball control). The good validity of the STARtest is also reflected in the fact that the test comprises various categories of basketball-specific movements, with a change between movement categories approximately every 2-3 seconds, which is designed to be representative of a basketball game[1-3].

Since research has shown the difficulties of predicting future performance level[12,14], it might be helpful to monitor the performances of youth basketball players with an objective test, such as the STARtest, to supplement the subjective opinion of coaches and trainers regarding their basketball players. The STARtest could be supportive for monitoring and evaluating the individual development of change-of-direction speed and ball control of youth players, which in turn can motivate players to train these skills. It is important for coaches and trainers to monitor players' individual development to gain insight into the progress during a specified period[13]. Results of this study showed that a change of 0.92 seconds for the STARtest without ball (change-of-direction speed), and 1.13 seconds for the STARtest with ball (ball control) is necessary to mention a significant increase or decrease in performance (i.e., SDD). The results of this study can be used by coaches and trainers as input for training programs for their basketball players.

Conclusion

This study showed that the STARtest, which has already shown its practical value for coaches and trainers, is a scientifically reproducible and valid test to measure and monitor the change-of-direction speed and ball control of talented youth basketball players. Coaches and trainers can easily administer the test themselves, since the STARtest can be performed on a basketball court and no expensive or special equipment is needed. It is therefore recommended to coaches and trainers to use the STARtest in their training programs to monitor and evaluate the individual change-of-direction speed and ball control of their basketball players. Coaches and trainers are advised to monitor their players at least twice a year to obtain data about their development within a season and between seasons. In this way, players are evaluated individually, which is very useful since each player can improve their own weaknesses to increase their performance level.

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Chapter 5

The importance and development of ball control and self-regulatory skills in basketball players for different positions

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Abstract

This study first investigated the importance of ball control and self-regulatory skills in achieving the elite level of performance in basketball. The second aim was to gain insight into the development of, and association between ball control and self-regulatory skills that contribute to achieving the elite level, with taking into account positional differences. Talented male players (N=73; age 16.56 ± 1.96) completed the STARtest to measure ball control and a questionnaire to measure self-regulation from 2008-2012. Results showed that reflective skills were most important to achieve the elite level (OR = 11.76; $p < 0.05$). There was no significant improvement in reflection over time for guards, forwards, and centers. Improvement in ball control was evident for guards ($r = -0.65$; $p < 0.05$). In addition, guards and forwards had better ball control compared to centers ($p < 0.01$). For those two positions, negative correlations were found between reflection and ball control, i.e., higher reflection was related to better ball control (guards $r = -0.19$; forwards $r = -0.18$) in contrast to centers ($r = 0.34$). It is concluded that reflective skills are important to achieve the elite level. Ball control seems especially important for guards in whom an association between reflection and ball control was shown, and the highest rate of development was found.

Keywords: talent development, self-regulation, adolescence, performance, sport

Introduction

Adolescent basketball players aiming to achieve the elite level of performance need to develop outstanding performance characteristics, such as a high level of physiological (e.g. endurance and speed) and technical characteristics (e.g. ball control)[1]. Ball control is a particularly important skill for basketball players, since dribbling the ball while changing direction is required to achieve successful performances[1-3]. However, the importance of these skills can vary between different playing positions.

Basketball players can be roughly divided into three playing positions (guard, forward, center), which each have slightly different roles to perform. Due to these various requirements, different skills are needed to play well in each playing position[4-6]. Guards initiate the offense and therefore need to be fast and agile with the ball. Forwards are often the best attacking players in a team, whereas centers need to be very tall and physically strong to score and block opponents' shots. These position-related demands are reflected in, for example, anthropometrical4, physiological[4], and technical differences between players[7]. Research has shown that guards are the smallest players and the fastest on sprint and dribble tests (i.e., have best ball control). Centers are the tallest players, performing worst on sprint and dribble tests[4,6-10].

Talented athletes often spend many hours in training to improve those skills which are especially important in their chosen sport (e.g., ball control in basketball)[11]. According to Ericsson et al. (1993), at least 10,000 hours or ten years of deliberate practice are needed to attain expertise[12]. These years of training can be labelled as the sampling (ages 6-13), specializing (ages 13-15) and investment years (ages ≥ 16), in which the amount of training hours in one main sport increases over the years[13,14]. During these hours of deliberate practice, athletes should remain cognitively engaged in order to improve their performance continuously[14,15]. This statement is in line with Zimmerman's theory of self-regulated learning; athletes who want to improve themselves should be metacognitively (reflection, planning, monitoring, evaluation), motivationally (effort, self-efficacy), and behaviourally active in their own learning[16-18]. Models of self-regulated learning incorporate cognition, motivation, and behaviour making them well suited to explain sport training, in which deliberate practice has been given a central role[12,19]. Examples of such models are Zimmerman's tri-phasic model with the forethought, performance, and reflection phase[20] as well as Winne and Hadwin's (1998) self-regulated learning model which holds four, loosely sequenced phases[21]. This last model distinguishes task perceptions, goal setting and planning, task enactment, and adaptation (optional phase). These models can be used to explain performance improvement. For example, a player wants to improve his ball control since this is an important skill in basketball considering the task requirements of this game. The player needs then to be aware of his own weaknesses and strengths related to his ball control (reflection), and needs to make a plan how to improve this skill (planning). In addition, he should monitor and evaluate the process, should put effort in it and believes that he is able to achieve his goal (self-efficacy)[16,18,22]. This self-regulated learning can for example be expressed by players by being on time at training, taking initiative during exercises, and asking for feedback from the trainer[23,24]. Research has shown that higher skilled athletes have better self-regulatory skills, especially reflection[20,25,26]. Athletes with a high level of reflection are expected to improve themselves on those skills which are important for their position. Consequently, they are hypothesized as more often attaining the elite level of performance compared to players with lower reflection scores[24,27].

This study first investigated the importance of ball control and self-regulatory skills for talented basketball players in order to achieve the elite level of performance in adulthood (>20 years). The second aim was to gain insight into the development of, and association between ball control and the self-regulatory skills that contribute to achieving the elite level (based on the results of aim 1), while considering positional differences.

Methods

Participants

A longitudinal dataset consisting of self-regulatory skills and ball control for 73 adolescent male basketball players was used in this study. To investigate the importance of ball control and self-regulatory skills in order to achieve the elite level of performance (> 20 years in 2014), a subgroup of 29 players was analysed. Eleven basketball players (3 guards, 5 forwards, 3 centers) achieved the elite level of performance (the highest level in the Dutch basketball competition) (mean age 17.96 ± 0.92 during measurements). Eighteen players (4 guards, 11 forwards, 3 centers) did not achieve the elite level of performance (second level or lower) (mean age 18.16 ± 1.17 during measurements). There were no significant differences in age and amount of training hours between both groups at time of measurement ($F(1,27) = 0.23$; $p = 0.63$; and $F(1,26) = 3.58$; $p = 0.07$, respectively).

For the second aim, data of all 73 adolescent male basketball players were analysed to investigate the development of ball control and self-regulatory skills that contribute to achieve the elite level (based on the results of aim 1) (guards: n=22, age = 16.42 ± 1.89; forwards: n=38, age = 16.61 ± 2.04; centers n=13, age = 16.63 ± 1.84; total: age = 16.56 ± 1.96). An overview of the number of measurement events per age group is shown in table 5.1. Age groups were defined using the whole year as the mid-point, i.e., 15 years = 14.50 – 15.49 years. All the players were from one of the selection teams (U14, U16, U18, or U20) and competed at the highest level for their age category in the Netherlands. They had 6.16 ± 2.23 years experience at a basketball club and trained 14.56 ± 5.12 hours per week. Players and parents/guardians were informed about this study and provided their written consent. This study was approved by the local ethics committee.

Table 5.1: Number of measurements per player for each age category.

Age (years)	Number of measurements									
	1	2	3	4	5	6	7	8	9	Total (guards – forwards – centers)
13	0	6	2	3	1	1	0	0	0	13 (5 – 7 – 1)
14	2	7	3	6	1	3	0	1	3	26 (10 – 11 – 5)
15	1	6	17	4	7	4	0	2	3	44 (11 – 27 – 6)
16	0	12	5	5	7	5	0	2	4	40 (11 – 23 – 6)
17	2	11	1	5	4	4	1	3	8	39 (13 – 15 – 11)
18	1	4	2	1	5	7	2	4	5	31 (15 – 10 – 6)
19	0	8	5	2	7	4	3	3	2	34 (9 – 23 – 2)
20	1	4	1	2	3	2	1	1	2	17 (2 – 11 – 4)
Total measurements (n)	7	58	36	28	35	30	7	16	27	244 (76 – 127 – 41)
Number of players	7	29	12	7	7	5	1	2	3	73 (22 – 38 – 13)

Ball control

The STARtest was used to measure the ball control performances of basketball players. The STARtest consists of basketball-specific movements (figure 5.1). Players take off with a flying start through point AB, at which point the timer starts. Next, they dribble the ball forwards to points C and D, backwards to point E, make sideward slides to point F, dribble forwards to points C and D, and then follow the same pattern on the other side of the field (i.e., points G, H, and C). Finally, players dribble forwards to point D and point AB, at which point the timer stops. Time was measured using electronic timing gates (Eraton BV, The Netherlands). Before the real measurement started, players walked through the test pattern once, to make sure it was clear to them. During the test, the players were supervised by leaders to prevent them from making mistakes. The reproducibility (reliability and agreement) and validity of the STARtest have been confirmed[28].

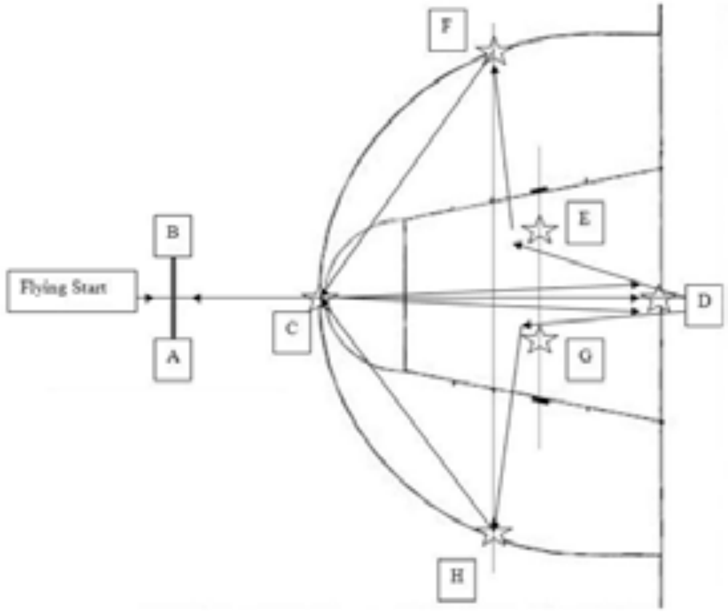

Figure 5.1: Course of the STARtest.

Self-regulation of learning

The self-regulatory skills of the basketball players were measured using the self-regulation of learning self-report scale (SRL-SRS)[29]. This self-reported questionnaire consists of 46 questions regarding the self-regulatory skills reflection (5 items, 1-5), evaluation (8 items, 1-5), planning (8 items, 1-4), self-monitoring (6 items, 1-4), effort (9 items, 14), and self-efficacy (10 items, 1-4). The reliability and validity of the SRL-SRS was confirmed by Toering and colleagues (2012)[29].

Procedure

All data were collected during the basketball players' adolescence from 2008 to 2012, with multiple measurements each season. Level of performance of players aged > 20 was established in 2014. The players' ball control was measured multiple times each season, while self-regulatory skills were measured once per season. All the tests were carried out in the afternoon, during regular training hours at an indoor sports hall. Players started with a ten-minute warm-up and were then randomly divided into two groups: one group started with the STARtest, while the other group started completing the SRL-SRS.

Data analysis

A binary logistic regression analysis was performed with IBM SPSS Statistics software (version 20.0; Inc., Chicago, Illinois, United States of America) to investigate the importance of ball control and self-regulatory skills in achieving the elite level of performance in adulthood. The self-regulatory skills were, based on theory, divided in a low (for reflection and evaluation 1-4; for planning, self-monitoring, effort and self-efficacy 1-3) and a high group (for reflection and evaluation 4-5, for planning, self-monitoring, effort and self-efficacy 3-4)[30]. For ball control linearity was checked and not confirmed. Therefore, ball control was divided into five groups with an interval of 0.60 seconds per group (i.e., players with a score of 17.80 – 18.40 seconds on the STARtest with ball were taken together in group 1, players with 18.41 – 19.00 seconds in group 2 and so on). The Enter method was used to examine the relative contributions of all skills for attaining the elite level.

For the second aim, multilevel modelling was used to analyse the longitudinal data. Multilevel models can handle data which are not independent, as is common in a longitudinal design where measurements are nested within players. This advanced statistical method permits variation between the time and number of measurements between players[31]. In longitudinal designs, players often miss one or more measurements due to, for example injuries, illness or drop-out. Using the MLwiN 2.27 software package, two empty models were created (i.e., for reflection and ball control) as starting points to investigate the development of both skills. The level 1 scores of the model represent the measurements within individual players and level 2 scores represent the differences between individual players. Random intercepts were considered, allowing a unique intercept for each individual player. In addition, random slopes were entered into the models to properly account for correlations among repeated measurements within individuals.

Possible predictors for the multilevel models were age and position, which were added to investigate their influence on the development of reflection and ball control. The predicted variables were entered separately into the initial model; during each step goodness of fit was evaluated by comparing the -2*Log likelihood (IGLS deviance) of the previous model, with the most recent model. Variables which were not statistically significant ($p > 0.05$) were removed from further analysis[32]. We prepared graphs based on the multilevel models created to illustrate the development of reflection and ball control for all three playing positions.

Pearson correlations were calculated for each position between age, reflection, and ball control to investigate the rate of development of both skills and their association. The measurement taken closest to the age of 16 was included for each player in this analysis, since this was the mean age of the overall group. A correlation of < 0.10 was interpreted as trivial, $r = 0.10 – 0.30$ as small, $r = 0.30 – 0.50$ as moderate, $r = 0.50 – 0.70$ as large, $r = 0.70 – 0.90$ as very large, and $r > 0.90$ as nearly perfect[33]. Differences between correlations were investigated using Z scores[34]. The statistical significance for all the analyses was set at $p < 0.05$.

Results

Descriptive statistics of ball control and self-regulatory skills of players who did and did not achieve the elite level of performance in adulthood are shown in table 5.2.

Table 5.2: Descriptive statistics of ball control and self-regulatory skills of players who achieved the elite and non-elite level of performance in adulthood.

	Elite (n = 11)	Non-elite (n = 18)	Total (n = 29)
Ball control (s)	19.62 ± 1.14	19.67 ± 1.02	19.65 ± 1.05
Reflection (1-5)	4.29 ± 0.29*	4.04 ± 0.31	4.14 ± 0.32
Evaluation (1-5)	3.85 ± 0.36	3.82 ± 0.45	3.83 ± 0.41
Planning (1-4)	2.80 ± 0.44	2.72 ± 0.54	2.79 ± 0.50
Self-monitoring (1-4)	2.90 ± 0.39	2.82 ± 0.48	2.85 ± 0.44
Effort (1-4)	3.[illegible] ± 0.38	2.94 ± 0.36	3.[illegible] ± 0.34
Self-efficacy (1-4)	3.20 ± 0.46	3.05 ± 0.41	3.11 ± 0.43

*Players who achieved the elite level of performance scored significantly higher compared to players who did not achieve this level ($F_{(1,27)} = 4.62$, $p < 0.05$).

The binary logistic regression showed that only reflective skills had a significant contribution to achieving the elite level of performance in adulthood (OR = 11.76; 95% CI = 1.34-102.7; $p < 0.05$).

The development of reflection and ball control for each playing position are shown in figures 5.2 and 5.3, respectively. Age and position were no significant predictors in the multilevel models ($p > 0.05$). There was a moderate but not significant correlation between age and reflection for guards ($r = 0.35$). A trivial and small, also not significant, correlation was found for forwards ($r = -0.03$) and centers ($r = 0.18$). No differences between the three playing positions were found for the rate of development of reflection ($p > 0.05$). Regarding ball control, a large and significant correlation with age was found for guards ($r = -0.65$). In addition, guards showed the highest rate of development over the years ($z = 2.33$; $p < 0.05$). A small, non-significant, correlation between age and ball control was found for both forwards and centers ($r = -0.11$ and $r = 0.11$, respectively). Regarding the correlation between reflection and ball control, a small but negative correlation was found for guards ($r = -0.19$) and forwards ($r = -0.18$) (i.e., a higher score on reflection indicates better ball control (less time needed for the test)). In contrast, a moderate but positive correlation between both skills was found for centers ($r = 0.34$).

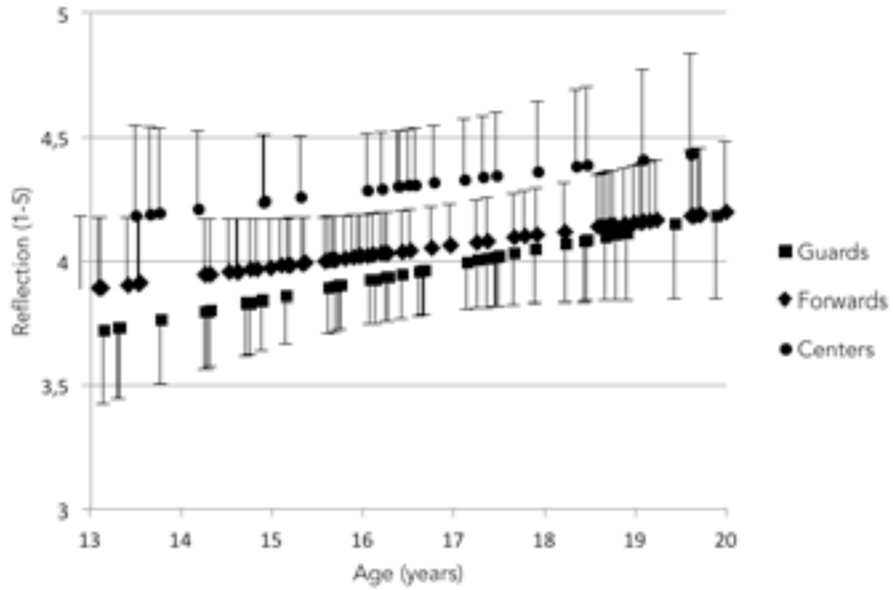

Figure 5.2: Development of reflection for players of the guard, forward, and center position. Standard deviations are only illustrated in one direction in order to maintain clarity.

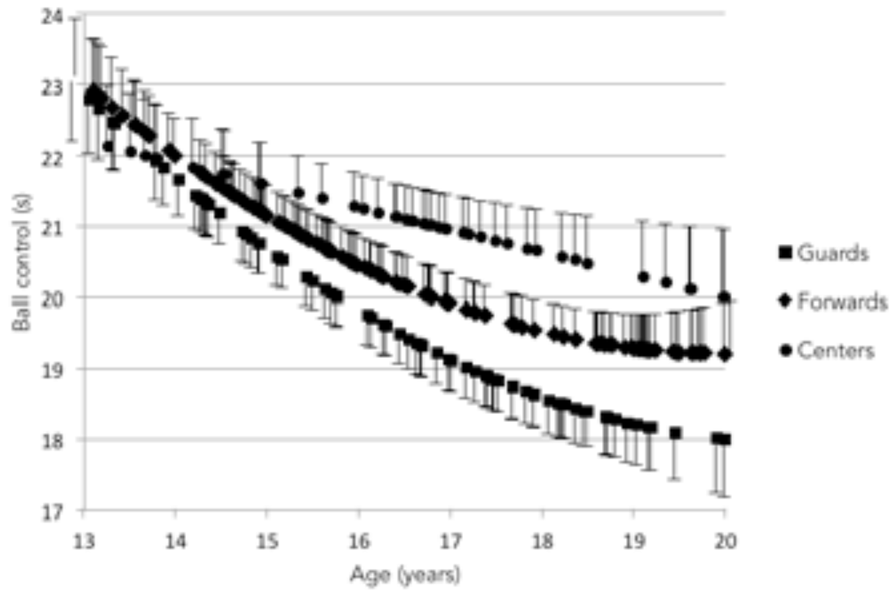

Figure 5.3: Development of ball control for players of the guard, forward, and center position. Standard deviations are only illustrated in one direction in order to maintain clarity.

Discussion

This study examined the importance of ball control and self-regulatory skills in achieving the elite level of performance in basketball. Furthermore, the development of ball control and reflection (as the most important self-regulatory skill), and their association was investigated while considering positional differences.

In order to attain the elite level in basketball, players need to develop skills that are meaningful for their position. As shown in literature ball control is an important skill, especially for those playing at the guard position. This is also reflected in the results of our study. We found that ball control improved with age, especially between ages 13 and 17, which is in line with other research on the dribble performance of talented athletes[35,36]. Moreover, it was shown that guards and forwards displayed better ball control performance than centers, with the strongest development for guards. In addition, a negative correlation between reflection and ball control was found for guards and forwards, which indicates that players with better reflective skills have better ball control (i.e., they need less time for the STARtest). Guards and forwards could be using their reflective skills to improve ball control, while centers use their reflective skills to improve other skills more important for their position. However, as the correlations were not that strong, and we did not ask the players about their specific use of reflection, we were not able to verify this suggestion. In order to further explore the link between reflection and ball control, it is suggested to observe and interview players before, during, and after training hours. We expect, for example, that the later elite players are more focused on the skill they want to improve compared to later non-elite players, as is also shown in research of Cleary and Zimmerman (2001)[20]. The basketball players in their study with a higher level of reflection were more aware of their performances, indicated by more frequent use of specific attributes (e.g., 'I did not bend my knees enough') rather than using general attributes to their failures and successes in performing a free throw. This enables them to reflect more specific on their previous performance in order to select technique-specific strategies (e.g., 'keep my elbow in') to improve future performance.

The scores on all aspects of self-regulation of the basketball players in this study were slightly higher compared to those of other talented athletes[25,27,30]. From all these self-regulatory skills, it is shown that reflective skills were most important in achieving the elite level of performance in adulthood. Moreover, our results revealed that from the age of 13, talented basketball players with better reflective skills (i.e., score > 4 on the SRL-SRS (strongly agree with the statements)) are eleven times more likely to achieve the elite level of performance. This is in line with other studies which showed that better performing athletes have better reflective skills, indicating the importance of reflection for talented athletes aiming to achieve high level of performance in sports[25-27,30]. According to the definition of reflection[37], athletes with good reflective skills are more aware of their performance and are able to improve the skills which are most important for their position, which in turn could lead to a greater likelihood of achieving the elite level of performance.

A limitation of this study is the relative small sample size when considering the differences between players in achieving the elite and non-elite level of performance. This is caused by the fact that within a group of talented players, only a few will reach the top in their sport[38]. Another methodological issue in this study is the use of a self-reported questionnaire (SRL-SRS). The results of self-reported questionnaires can be biased by social desirability, given the pressures of team selection procedures. However, the players for this study had already been selected for their team when they completed the questionnaire. Despite these limitations, the results of this study offer further insight into how different playing positions achieve the elite level of performance. Furthermore, longitudinal and prospective studies of players as performed in this study are rare. It improves our understanding of the development of adolescent basketball players considered talented into elite or non-elite athletes at age > 20.

Conclusion and practical applications

Acknowledging other important aspects related to basketball talent development, this study provides increased understanding of the development of talented basketball players through adolescence related to technical and psychosocial skills. Our results showed that having good reflective skills is important for players to achieve the elite level of performance at age > 20. In addition, our results revealed positional differences regarding the development of ball control in talented basketball players. Coaches, trainers and players should be aware of the position-related demands of the guard, forward, and center positions.

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Chapter 6

Towards the elite level in basketball; the importance of position-related characteristics and individual profiles

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Abstract

The aim was to identify general (position- and non-position-related) performance characteristics for talented basketball players of different positions. Furthermore, to investigate whether players who achieved the elite level of performance in adulthood performed better on performance characteristics during youth compared to players who did not attain this level, and whether the elites distinguish themselves from their talented peers more on position-related versus non-position-related characteristics. Finally, to examine whether developmental pathways towards the elite level are similar. MANCOVA's were performed regarding multidimensional characteristics of 61 basketball players (aged 16-19). Z-scores and radar graphs were shown for eleven players who attained the elite level in adulthood. Position-related characteristics were identified for guards and centers. Players who achieved the elite level performed better on general basketball-related performance characteristics compared to peers of the same position who did not achieved this level (Z-scores>0). In contrast to guards and forwards, centers who achieved the elite level distinguished themselves from their talented peers on position-related characteristics (effect size 2.64). Individual profiles showed multiple ways of development towards the elite level. Both position- and non-position-related characteristics are important for performance, while at the same time individual variations in the development towards the elite level should be acknowledged.

Keywords: talent development, athletic performance, athletes, individuality

Introduction

Research regarding basketball and other team sports has advocated a multidimensional and longitudinal approach to gain more insight into the development of talented youth athletes towards the elite level of performance in adulthood[1-3]. It has been shown that it is important for basketball players who aim to achieve the elite level of performance to excel in anthropometrical (e.g., height), physiological (e.g., repeated sprint), technical (e.g., ball control), and psychosocial characteristics (e.g., reflection and effort)[4-6]. These multidimensional performance characteristics are thought to improve over time through maturation, learning, and training[5,7,8].

Players within a basketball team can generally be divided into three playing positions (guard, forward, center), which all have slightly different requirements to perform well. Guards initiate and coordinate the offence in which ball control, i.e., quickly move the ball down the court, plays an important role[9-11]. Therefore, guards are often involved in high intensity activities such as sprints and dribbles[9,12]. Consistent with these task requirements, players of the guard position are often the smallest players with the best performances on sprint and agility tests[10,13,14]. In contrast to guards, centers are mostly positioned near the basket and are usually responsible for the team's defense during the game[9]. In order to execute these tasks well, centers are commonly the tallest and heaviest players[10,13,14]. Forwards are positioned between the guards and centers in the field, and play on a multidisciplinary position[9,15]. In summary, although players within a basketball team share general basketball-related performance characteristics, they have different position-related requirements in order to play well. Therefore, the general basketball-related performance characteristics can be divided into position-related and non-position-related characteristics.

In literature, it is suggested that there is variation in the development of general basketball-related performance characteristics of athletes who attain the elite level of performance[16-18]. Therefore, an individual focus seems valuable to gain more insight into the development of talented youth athletes[2,3,18]. Interviews with (inter)national athletes and their coaches emphasize the importance of multidimensional approaches with an individual focus towards athletes in order to optimize the pathway towards expertise[2]. However, it is a considerable challenge how to apply an individual focus in research regarding talent development. Till et al. (2013) made an attempt by introducing a method with Z-scores to compare performances of individual players with the performances of all other players of different ages and positions[3]. Cobley et al. (2014) elaborated this approach by using age-specific reference value to calculate the Z-scores[19]. To take this method one step further, the current study will use position-related reference values of players (aged 16-19) to calculate Z-scores (i.e., guards will only be compared with guards, forwards with forwards, and centers with centers).

This study investigated three aims to unravel the development of talented youth basketball players in more detail. The first aim was to investigate whether it was possible to identify position-related characteristics for each playing position. The second aim was to examine whether basketball players who achieved the elite level of performance in adulthood perform better during youth (16-19 years) on the general basketball-related performance characteristics (position-related and non-position-related) than their peers who did not attain the elite level, and whether, compared to their talented peers, the elite players perform better at position-related characteristics than at non-position-related characteristics. Finally, the individual development of the general basketball-related performance characteristics at age 16-19 of elite players of different playing positions (2x guard, 2x forward, 2x center) were demonstrated to illustrate possible individual differences in their pathways towards the elite level.

Methods

Participants

Male basketball players aged 16-19 of one of the regional training centers in the Netherlands were monitored in a multidimensional and longitudinal way. The study included 1056 data points from 61 individual basketball players. Anthropometrical, physiological, technical, and psychosocial characteristics were measured on twelve different test periods during the seasons 2008-2009 to 2012-2013. The basketball players had on average 7.00 ± 2.04 years of experience at a basketball club. This study focused in particular on players who attained the elite level in adulthood (age > 20 years; n=11). The elite level of performance was defined as playing at the highest level possible in the Dutch basketball league. The study was approved by the ethics committee of the local university, and players and parents/guardians gave written consent to participate.

Measurements

Height measurements (± 0.01 m) were performed with a body length meter while players were standing barefoot against a wall (Schinkel Medical, Nieuwegein, The Netherlands). The plan of Frankfort was used to ensure all measurements have been carried out the same way[20]. In the same position, both arms were spread horizontally at shoulder height to measure the wingspan from the longest fingertip at one hand to the longest fingertip at the other hand.

Players performed the Shuttle Sprint and Dribble Test (SSDT) to measure the (repeated) sprint (without ball) and (repeated) dribble (with ball) as suggested by Lemmink et al. (2004)[21]. Time measurements were performed with photocell gates (Eraton BV, Weert, The Netherlands). Outcome measures consist of the fastest time of the three attempts (s), and the total time of the three attempts together (s) for the sprint as well as dribble part. The reliability and validity of the SSDT has been confirmed[21].

The STARtest was used to measure change-of-direction speed (without ball) and ball control (with ball) as suggested by te Wierike and collegues[22]. This basketball-specific test consists of a trajectory in which player had to sprint and dribble in different directions (forwards, backwards, sideways). Time measurements were performed with electronic timing gates (Eraton BV, Weert, The Netherlands). Outcome measures were change-of-direction speed (s) and ball control (s). The reproducibility and validity of this test has been proven[22].

Reflection and effort are two components of self-regulation[23]. Reflection is the extent to which players are able to appraise what they have learned and to adapt their past knowledge and experiences in order to improve future performance[24]. Effort is defined as the willingness to reach the set goals[24]. Both skills were measured with the Self-Regulation of Learning Self-Report Scale (SRL-SRS)[23]. Reflection was measured on a Likert scale from 1-5 (5 questions), and effort on a scale from 1-4 (10 questions). Reliability and validity of the SRL-SRS has been confirmed[23].

Statistical analysis

To investigate the first aim of this study, i.e., whether position-related characteristics can be identified for each playing position, Multivariate Analyses of Covariance's (MANCOVA's) were performed (IBM SPSS Statistics software version 20.0; Inc., Chicago, Illinois, USA). Due to missing values, three separate MANCOVA's were performed (i.e., for the anthropometrical, the physiological and technical, and the psychosocial characteristics) with the general basketball-related performance characteristics as dependent variables, position as fixed factor, and age as covariate. Age 15.50-16.49 was defined as 16 year, 16.50-17.49 as 17 year and so on. One mean score per age category was calculated for players with multiple measurements at the same age. A performance characteristic is considered position-related when the main effect for position is significant and players of that position have the best score compared with players of both other positions. Level of significance was set at 0.05.

Eleven players achieved the elite level of performance (guard n=3, forward n=5, center n=3). Z-scores were calculated to compare the performance of these elite players with the population (aged 16-19) of the corresponding position (Z-score = (individual score – mean score population) / SD (mean population)). For example, the performance characteristics of an elite guard are compared with the performance characteristics of all other guards in the age of 16-19 year. For tests in which a lower time indicates a better performance, the scores were reversed in the formula. A positive Z-score therefore always reflects a better performance compared to peers of the same position. To examine on which characteristics (position-related or non-position-related) elite players score best compared to the population, the mean Z-score of position-related characteristics are compared to the mean Z-score of non-position-related characteristics by using effect sizes (Cohen's d). An effect size of 0.20 was considered as small, around 0.50 as moderate, and around or > 0.80 as large[25]. Finally, to show individual pathways towards the elite level, individual radar graphs with Z-scores of the general basketball-related performance characteristics were made for two players of each position who achieved the elite level.

Results

Descriptive data per position and results of the MANCOVA's are shown in table 6.1.

Table 6.1: Descriptive data and results of the MANCOVA's of players aged 16 to 19 according to their playing position. Adjusted means ± standard errors are shown.

	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]

[illegible]

Results of the MANCOVA's showed that guards have the best score on repeated sprint-best of three ($F(2,99) = 3.45$; $p = 0.04$), change-of-direction speed ($F(2,99) = 11.91$; $p < 0.01$), repeated dribble-best of three ($F(2,99) = 13.98$; $p < 0.01$), repeated dribble-total ($F(2,99) = 5.15$; $p < 0.01$)), and ball control ($F(2,99) = 7.52$; $p < 0.01$). As such, these characteristics were defined as the position-related characteristics for guards. Height, wingspan, repeated sprint-total, reflection, and effort were defined as non-position-related characteristics for guards. Regarding the forwards, there were some characteristics in which these players performed better than guards or centers (for example repeated dribble-best of three), however, they never performed as best of the three positions. Therefore, no position-related characteristics were determined, only general basketball-related performance characteristics could be identified (height, wingspan, repeated sprint-best of three and total, change-of-direction speed, repeated dribble-best of three and total, ball control, reflection and effort). Centers on the other hand were significantly taller ($F(2,84) = 50.28$; $p < 0.01$), had a larger wingspan ($F(2,84) = 34.90$; $p < 0.01$), and scored highest on effort ($F(2,76) = 3.40$; $p = 0.04$) compared to the other position(s). Height, wingspan, and effort were consequently defined as the position-related characteristics for centers, while repeated sprint-best of three and total, change-of-direction speed, repeated dribble-best of three and total, ball control, and reflection were defined as non-position-related characteristics for centers.

Table 6.2: Z-scores of guards, forwards, and centers who achieved the elite level of performance in adulthood*.

[illegible]

Table 6.2 shows the Z-scores for the general basketball-related performance characteristics as well as for the position-related and non-position-related characteristics for guards, forwards, and centers who attained the elite level of performance in adulthood.

As shown in table 6.2, when they were aged 16-19, guards who attained the elite level in adulthood scored better on the general basketball-related performance characteristics compared to their peers who did not attain the elite level of performance (indicated by a positive Z-score of 0.18 ± 0.30). More specifically, it is shown that guards who attained the elite level performed better on both position-related and non-position-related performance characteristics compared to their peers who did not attain the elite level (Z-scores of 0.17 ± 0.20 for position-related and 0.20 ± 0.40 for non-position-related characteristics). In comparison to their peers who did not achieve the elite level, the guards who achieved the elite level did not score better on position-related characteristics than on non-position-related characteristics, indicated by the small effect size (0.09).

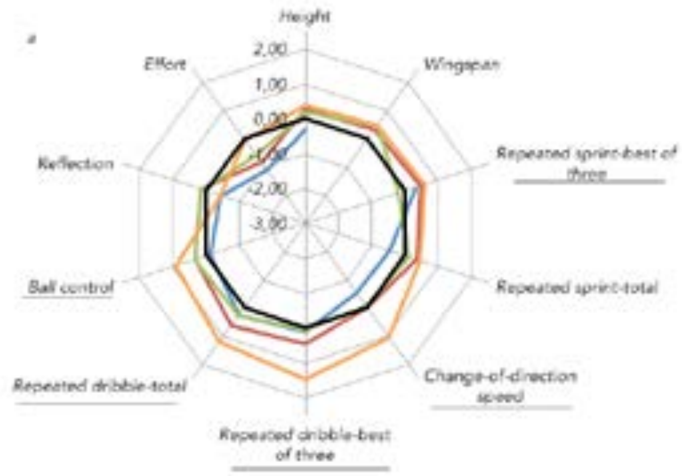
The forwards who achieved the elite level showed that when they were 16-19 years, they performed better on the general basketball-related performance characteristics than forwards who did not achieve the elite level of performance (Z-score of 0.35 ± 0.35).

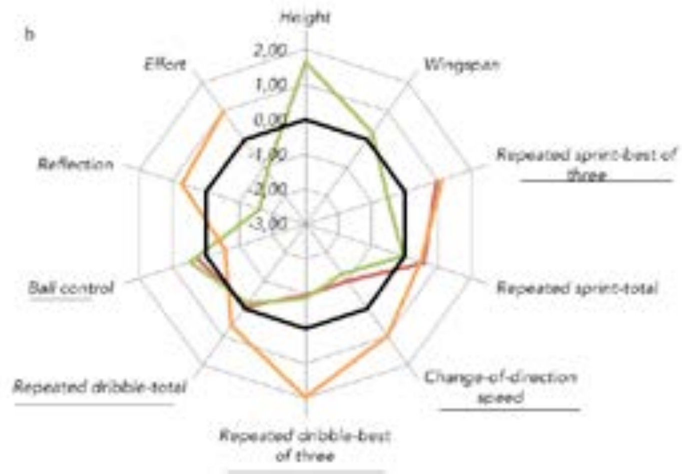
Centers who attained the elite level of performance also performed better compared to the non-elite centers on the general basketball-related performance characteristics (Z-score of 0.03 ± 0.58). More specifically, centers who attained the elite level of performance in adulthood performed better than centers who did not attain the elite level on position-related characteristics during their youth (Z-score of 0.76 ± 0.52), but not on non-position-related characteristics (Z-score of -0.28 ± 0.20). In comparison to their peers who did not achieve the elite level, the centers who achieved the elite level performed better on position-related characteristics than on non-position-related characteristics, indicated by the large effect size (2.64).

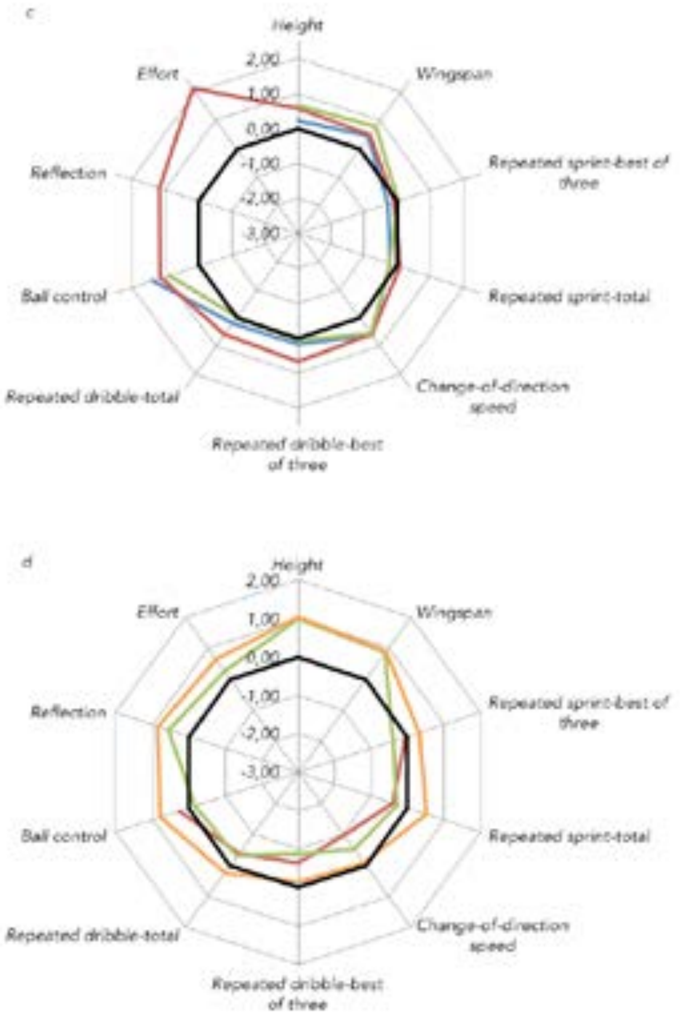
To illustrate the variation in individual pathways towards the elite level of performance in adulthood, figure 6.1 shows the developmental trajectories per characteristic (Z-scores) of two guards, two forwards, and two centers. Guard 1 (figure 6.1a) performed from the age of 17 better than peers playing at the same position, except for repeated sprint-best of three and the psychosocial skills (effort and reflection). In general, his superiority relative to his peers increased over the years (except at age 18). Figure 6.1b shows that guard 2 only excelled in the position-related and non-position-related characteristics compared to his peers at age 19 (except for ball control).

The development of both individual forwards were similar to a certain extent. Both forwards were taller and had a larger wingspan during their development compared to their peers. In addition, they increased these anthropometrical advantages over the years. Forward 1 (figure 6.1c) scored in particular better than his peers on the technical and psychosocial characteristics at age 16, 17, and 18. Forward 2 (figure 6.1d) does not show superiority relative to his peers of the same position until the age of 19, except for anthropometrical and psychosocial characteristics.

Figure 6.1e and 6.1f demonstrate the development of two centers who achieved the elite level of performance in adulthood. Center 1 (figure 6.1e) showed much variation in his development over the years, while center 2 (figure 6.1f) showed in general an improvement in characteristics (compared to his peers of this position) from age 17 to 18. In addition, center 1 showed large advantages relative to his peers on anthropometrics and both psychosocial characteristics, while center 2 showed the best performances compared to peers on two physiological characteristics.







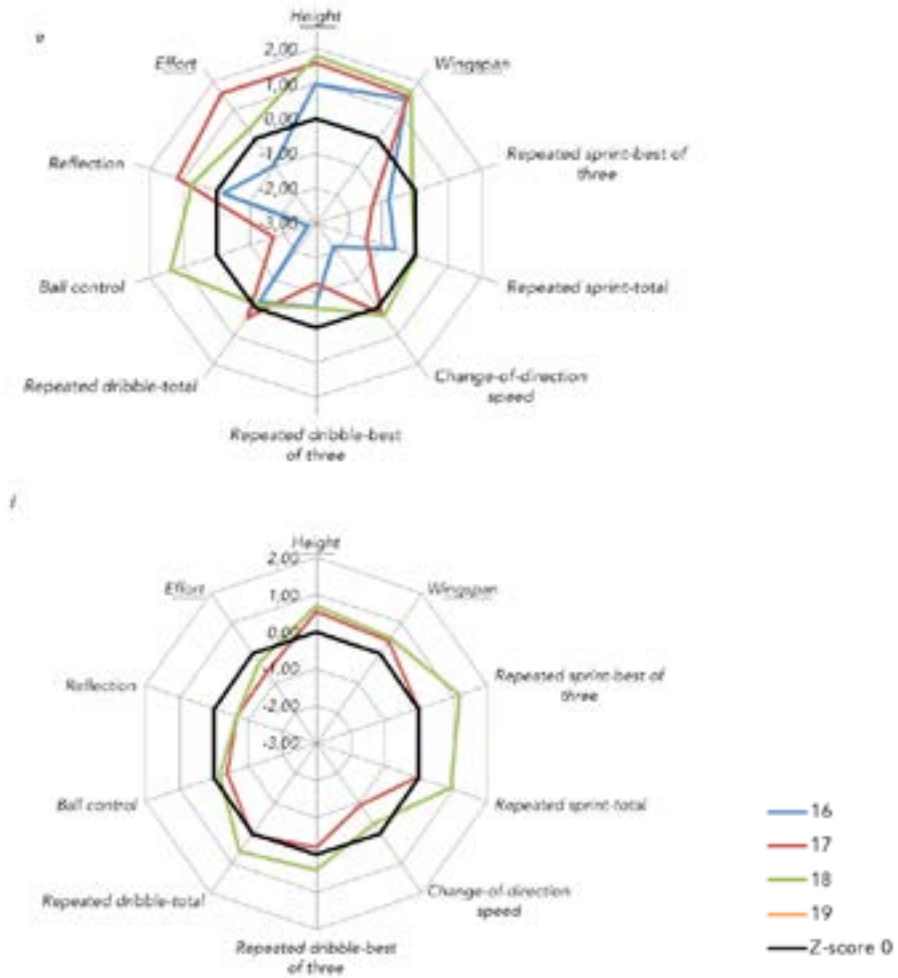


Figure 6.1: Individual profiles (Z-scores) of two guards (a and b), two forwards (c and d), and two centers (e and f) who all attained the elite level of performance in adulthood. A higher Z-score reflects better performances compared to peers of the same position who did not achieved the elite level. Note: Position-related characteristics for guards and centers are underlined. Note: Bold line shows Z-score of 0.

Discussion

This study focused on the development of talented youth basketball players towards the elite level of performance, while taking into account positional and individual differences between players. The first aim was therefore to examine whether it was possible to identify position-related characteristics for each playing position. In addition, we investigated whether basketball players who achieved the elite level of performance in adulthood outscored their peers who did not attain the elite level on the general basketball-related characteristics during youth (16-19 years), and whether the elite players perform better at position-related characteristics compared to non-position-related characteristics. Finally, individual profiles of basketball players during their development towards the elite level of performance in adulthood were illustrated to demonstrate possible differences. The results of the first aim showed that there were position-related characteristics for guards and centers. Related to the second aim, it was shown that players of all three positions who attained the elite level in adulthood performed better on the general basketball-related performance characteristics at the age of 16-19 years compared to their peers of the same position who did not attain the elite level. Elite centers distinguished themselves especially on the position-related characteristics. Moreover, different pathways to achieve the elite level in adulthood have been identified for talented basketball players.

The position-related characteristics for players of the guard and center position as indicated by literature are confirmed in this study[9,13,14]. For centers it was found that their position-related characteristics are highly important to attain the elite level of performance since these players scored higher on these position-related characteristics compared to their non-position-related characteristics. This finding can be explained by the importance of height as found in this study. Results showed, as expected, that centers are the tallest players within a team. A more remarkable finding was that also within the group of guards and forwards, the tallest players were the ones who achieved the elite level of performance (indicated by positive Z-scores for the anthropometrical characteristics). This indicates the importance of height in basketball not only for centers, but also for players of the guard and forward position. Since height is categorized as a position-related characteristic for centers and not for guards, a high Z-score is added to the position-related characteristics for centers, while this high Z-score for the guards is added to the group of non-position-related characteristics. This might explain the differences in importance for position-related characteristics for players of both positions.

The abovementioned results already imply differences between players of the guard, forward, and center position in their development towards the elite level of performance. The individual radar graphs enhance this finding by not only showing differences between the playing positions, but also within players of the same position. The individual development of two elite players of the same position were compared with each other and showed variations. For example, center 1 scored better on effort and reflection at age 17 and 18 compared to peers of this position (indicated by positive Z-scores), while center 2 scored worse on these characteristics compared to the performances of the other centers. This finding is in line with recent studies that also indicated a non-linear trajectory in the majority of athletes who achieved the elite level[2,19,26].

In addition to the multidimensional and longitudinal aspects, this study considered individual profiles towards talent development which is suggested by recent literature[2,3,19]. For future research, it is suggested to make the reference values even more specific by using position as well as age-specific groups (i.e., comparing the individual scores of a 16-year-old guard with only 16-year-old guards). Due to a small number of players within each reference group this method was not applicable in this study.

Conclusion

It was possible to identify position-related performance characteristics for guards (repeated sprint-best of three, change-of-direction speed, repeated dribble-best of three, repeated dribble-total, and ball control) and centers (height, wingspan, effort). Players of all positions who attained the elite level of performance in adulthood performed better on the general basketball-related performance characteristics during their youth (16-19 years) compared to later non-elite players. Moreover, centers distinguished themselves most on their position-related characteristics compared to their non-position-related characteristics. Finally, it can be concluded that multiple pathways with different performances on the position-related and non-position-related characteristics can lead to the elite level of performance in basketball. A multidimensional, longitudinal approach with an individual focus (for example with Z-scores) seems, therefore, promising for coaches and trainers to monitor the performance development of their talented youth basketball players.

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Chapter 7

Psychosocial factors influencing the recovery of athletes with anterior cruciate ligament injury: A systematic review

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Scandinavian Journal of Medicine & Science in Sports, 2013, 23: 527-540

Abstract

This review describes the psychosocial factors that affect recovery following anterior cruciate ligament (ACL) injury and reconstructive surgery in athletes. A systematic search in literature with inclusion and exclusion criteria on PubMed, PsycINFO, and Embase was performed. Articles used in this review were divided into five different parts according to the biopsychosocial model of Wiese-Bjornstal, with the addition of intervention studies. The results showed that a high internal Health Locus of Control and a high self-efficacy were useful cognitive factors to facilitate the recovery. Athletes with a low level of fear of reinjury had the best knee outcome after the injury followed by a reconstruction. In addition, athletes who returned to sport had less fear of reinjury and were more experienced and established athletes compared with athletes who did not return to sport. Furthermore, researchers showed that there was a positive relation between goal setting and adherence, which in turn yielded a positive relation with the outcome of the rehabilitation of an ACL injury. There were several psychosocial interventions that appeared to be facilitating the rehabilitation process.

Keywords: sports, rehabilitation, psychology, injuries

Introduction

Anterior cruciate ligament (ACL) injuries happen about 250,000-300,000 times a year[1]. The number of ACL injuries has increased sharply over the last years because of higher sport participation rates and an increasing exposure to higher-risk sports[1,2]. Basketball, soccer, volleyball, handball, gymnastics, skiing, and martial arts are sports with the highest risk of ACL injury. The injury occurs most often during landing after jumping, changing direction, running, sudden stoppage (deceleration), and overextension of the lower leg[3].

One of the adverse consequences of injuries is that an athlete cannot train full-time in his or her sport. Even worse, it might be the reason why talented athletes stop performing their sport[4]. To minimize these negative consequences, it is very important to ensure a successful outcome of the rehabilitation process (i.e., return to pre-injury level of activity) with regard to the ACL injury whether or not reconstructive surgery is performed. Besides the physical recovery of the injury, psychosocial aspects of the rehabilitation are of significant value. These psychosocial factors are in particular important for the recovery of an ACL injury, because this injury requires a long rehabilitation process and it is uncertain whether a player is able to return to his previous level again.

According to Wiese-Bjornstal (2010), the psychosocial responses of injured athletes consist of cognitive, affective, and behavioral factors[5]. As shown in figure 7.1, these factors interact with each other and again consist of several components. Cognition concerns the conscious assessments athletes make after an injury. Furthermore, the affective factors include emotions, feelings, and mood disturbances such as depression, anxiety, low vigor, fatigue, grief, and burnout. The behavior of the athlete refers to someone's effort, actions, and activities with regard to the injury. This behavior is in turn influenced by an athlete's cognition and emotions. Together, these three factors play an important role in the outcome of the injury.

Figure 7.1 indicates that psychosocial factors are related with the outcome of sport injury rehabilitation. In order to improve this rehabilitation, it is important to know which psychosocial factors can contribute to a good recovery (i.e., return to pre-injury level). Therefore, the purpose of this review is to give an overview of literature of the psychosocial factors that have an effect on the recovery of ACL injuries and reconstructive surgery in athletes.

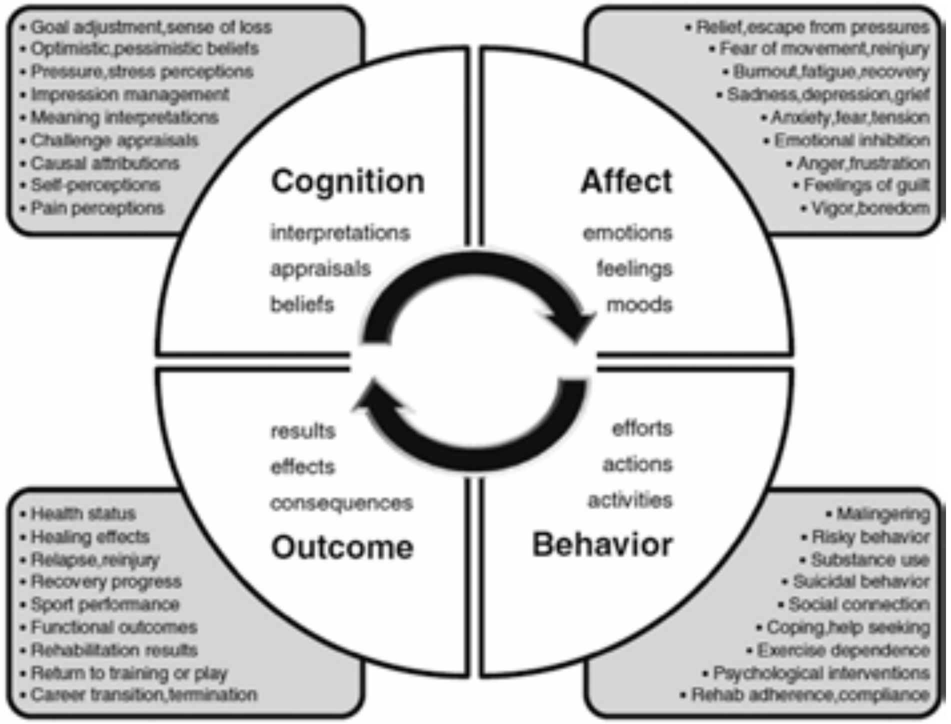

Figure 7.1: Biopsychosocial model of post-sport injury response and recovery (Reprinted by Wiese-Bjornstal, 2010)[5].

Methods

Systematic search

In this review, different search machines were used to find literature about the psychosocial recovery of an ACL injury. PubMed, PsycINFO, and Embase were searched in a systematic way with multiple keywords (table 7.1, total N=523). The articles had to be published in the time period 2001–2011. In order to find the most relevant articles, exclusion criteria were applied based on titles and abstracts. Articles about surgical methods for reconstruction of the ACL, measures, risk factors, prevention factors, non-psychosocial factors, case reports, epidemiology, physical rehabilitation, gender differences, and articles with no full text were excluded (n=493). Furthermore, articles that were found twice (n=6) were included only once. The remaining 24 articles were divided into five parts according to the biopsychosocial model, with addition of intervention studies (table 7.3).

Table 7.1: Systematic research.

	Keywords	Limits	Results
PubMed	[illegible]	[illegible]	[illegible]
PsycINFO	[illegible]	[illegible]	[illegible]
Embase	[illegible]	[illegible] 2001-2011 Humans	[illegible]

Methodological quality

To determine the methodological quality of the literature in this study, all articles were evaluated. The evaluation for quantitative studies was based on the criteria of Law et al. (1998)[6]. According to these criteria, articles were assessed on their purpose, literature background, design, sample, outcomes, intervention, results, dropouts, conclusions, and implications. The outcome of this evaluation for each question resulted in 1 (meets the criteria), 0 (does not meet the criteria), or NA (not applicable). Questions 8 and 9 only met the criteria when the reliability or validity was mentioned for all the measuring instruments used. The scores of all 16 questions together represent the methodological quality of the study. Articles with a score above 7 were considered as a good methodological quality and articles with a lower score were considered as worse methodological quality[6].

In case of qualitative studies, these were evaluated with criteria based on Letts et al. (2007)[7]. These studies were judged by their purpose, literature background, design, theoretical perspective, method, sampling, data collection, procedural rigor, data analysis, theoretical connections, overall rigor, conclusions, and implications. The way of assessing these components was similar to the method for quantitative studies. However, the maximum score here was 13.

Table 7.2: Methodological quality of the studies (n=24)[a].

Question number[b]	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Total
Study																	
Cognition																	
Nyland et al. (2006)[8]	1	1	1	1	1	1	0	0	na	1	1	0	1	1	1	0	11
Thomeé et al. (2007a)[9]	1	1	1	1	1	1	0	0	na	1	1	1	1	1	0	1	12
Thomeé et al. (2007b)[10]	1	1	1	1	1	1	0	0	na	1	1	0	1	1	1	0	11
Thomeé et al. (2007c)[11]	1	1	1	1	1	1	0	0	na	1	1	1	1	1	0	1	12
Affect																	
Brewer et al. (2007)[12]	1	1	1	1	1	1	1	0	na	1	1	0	1	1	1	1	13
Chmielewski et al. (2008)[13]	1	1	1	1	1	0	1	1	na	1	1	1	1	1	1	1	14
Heijne et al. (2008)[14]	1	1	1	1	0	1	0	0	na	0	1	0	1	1	1	1	10
Kvist et al. (2005)[15]	1	1	1	1	1	0	0	0	na	1	1	0	1	1	0	1	10
Langford et al. (2008)[16]	1	1	1	1	1	0	0	0	na	0	1	1	1	1	1	1	11
Behavior																	
Brewer et al. (2004)[17]	1	1	1	1	1	1	1	0	na	1	1	0	0	1	0	0	10
Carson & Polman (2010)[18]	1	1	0	1	1	1	0	0	na	0	1	0	1	1	1	1	10
Scherzer et al. (2001)[19]	1	1	1	1	1	1	1	0	na	1	1	0	0	1	1	1	12
Outcome																	
Cascio et al. (2004)[20*]	1	1	1	1	0	0	0	0	na	0	1	1	0	na	na	na	6
Gobbi & Francisco (2006)[21]	1	1	1	1	1	0	0	0	na	1	1	0	1	1	0	1	10
Lee et al. (2008)[22]	1	1	1	1	1	0	0	0	na	1	1	0	1	1	1	1	11
Shah et al. (2010)[23]	1	1	1	1	1	0	na	na	na	1	1	0	1	1	0	1	10
Swirtun & Renström (2008)[24]	1	1	1	1	1	0	0	0	na	1	1	0	1	1	0	1	10
Tripp et al. (2007)[25]	0	1	1	1	1	1	1	0	na	1	1	0	0	1	0	1	10
Intervention																	
Cupal & Brewer (2001)[26]	1	1	1	1	1	1	0	0	1	1	1	1	0	1	1	1	13
Maddison et al. (2006)[27]	1	1	1	1	1	1	0	0	1	1	1	0	1	1	0	1	13
Mankad et al. (2009)[28]	0	1	1	1	0	0	1	0	1	1	1	0	0	1	0	1	9
Myers et al. (2004)[29]	1	1	0	0	1	0	0	0	1	1	1	0	0	1	0	1	8
Rock & Jones (2002)[30]	1	1	1	1	0	0	0	0	1	0	1	0	1	1	0	1	9
Thomeé et al. (2010)[31]	1	1	1	1	0	1	0	0	1	1	1	0	1	1	0	1	11

Note: [a] Item score: 1 = fulfills criterion; 0 = does not fulfill criterion; na = not applicable.

[illegible]

[illegible]

Results

Table 7.2 shows the methodological quality of the 24 articles of this study. Most of the articles (n=23) were evaluated as a quantitative study and there were differences among their qualities. Chmielewski et al. (2008)[13] had the best methodological quality with a score of 14, while Myers et al. (2004) had a score of 8[29]. Overall, all of the quantitative studies scored above 7 points and thus can be considered of good methodological quality. The article of Cascio et al. (2004) was evaluated as a qualitative study and scored 6 points, which can be considered as moderate quality[20].

Characteristics and outcomes of the 24 included studies are presented in table 7.3, which is structured according to the model of Wiese-Bjornstal (2010) with the addition of the intervention component[5]. Participants included in the articles of this review had ages between 18 and 55 years and were active in different sports at different levels.

Table 7.3: Articles included in this review (N=24).

Author(s) (year)	N, Gender, Age (range/SD), design	Sport	Participants underwent surgical reconstruction yes/no/mixed (mixed = groups of participants underwent with and without reconstruction)	Psychosocial factor(s)	Measures	Outcome
Cognitive						
[illegible] (2008)	198, Male and female, 28.? years [illegible], Prognostic study	Basketball, American football, snow skiing, soccer, gymnastics, cheerleading, baseball, [illegible] volleyball, [illegible], [illegible] [illegible]	Yes	[illegible] (HEOC)	[illegible] HEOC [illegible] Multidimensional HEOC Survey, Form C	[illegible]
Thomeé et al. (2007a)[?]	116, Male and female, ?1.? years (18-55), [illegible] study		Mixed	[illegible] self-efficacy	K-SES SF-36 Coping Strategies Questionnaire (CSQ) Multidimensional Health Locus of Control (MHLC)	Self-reported symptoms, function and [illegible] were the most important [illegible] self-efficacy in patients with an ACL injury
Thomeé et al. (2007b)[?]	Group 1 ?8, Male and female, 2?.? years (1?-5?) Group 2 ?8, Male and female, 29.? years (1?-5?) Prospective, [illegible] study		Mixed	Self-efficacy	K-SES, Tegner Activity grading scale, Tegner scale, PAS, KOOS	K-SES has good [illegible] with significantly [illegible] self-efficacy during the rehabilitation [illegible] for patients with an ACL [illegible] as well as for patients who had undergone ACL reconstruction. Self-efficacy differed significantly with gender, age and physical activity level [illegible] rehabilitation process.
Thomeé et al. (2008)[?]	?8, Male and female, 2?.? (18-5?), [illegible] study		Yes	Self-efficacy	K-SES present, K-SES future	Patients' self-efficacy of knee function before surgery [illegible] possibly predict physical activity, symptoms and muscle function 1 year after ACL reconstruction
Affect						
[illegible] (2007)[?]	91, Male and female, 29.?? years (1?-5?), Correlational design		Yes	Positive and negative affect (Affect intensity, [illegible]), daily stress and physical activity	Numeric Rating Scale (NRS) and Profile of Mood States (POMS), Daily Diary, Affect Intensity Measurement	[illegible] and situational factors [illegible] daily pain and negative affect [illegible] daily pain [illegible]

					Scale (AIMS), [illegible] Inventory ([illegible]), [illegible] Questionnaire Revised ([illegible])	negative mood decreased over time when rehabilitation progressed. The decrease in negative mood was stronger in patients higher athletic identity and lower self esteem.
Chmielewski et al. (2008)[?]	97, Male and female, 21-19 years (±9.2), Cross-sectional		Yes	Pain and fear of movement/re-injury	Tampa Scale for Kinesiophobia (TSK-11), International Knee Documentation Committee (IKDC) and Medical Outcomes Study Short Form Health Survey (SF-36)	Level of pain decreased as rehab progressed after ACL reconstruction, and pain was associated with knee function. There was also a decrease of fear of movement/re-injury levels as rehab progressed. This was only associated with function of the knee when it was measured later in the rehabilitation process.
Heijne et al. (2008)[?]	10, Male and female, 24 years, Qualitative study		Yes	Athletes' thoughts, feelings and behaviour	Semi-structured interview	All patients were surprised during the rehabilitation process. It was much longer to recover than they expected. None of the participants was ready to return to sport after ACL surgery.

Kvist et al. (2005)[?]	84, Male and female, 18-59 years, Cohort study	Soccer, floorball, ice hockey, [illegible] and American football	Yes	Fear of re-injury	Tampa Scale of Kinesiophobia (TSK), Knee injury and Osteoarthritis Outcome Score (KOOS) and a general questionnaire	Half of the patients with an ACL reconstruction returned to their previous level of activity. Patients who did not return to their previous level of activity were more afraid of re-injury and had a worse knee-related quality of life than did those who returned.
Langford et al. (2009)[?]	87, Male and female, 27-28 years (18-40), Prospective longitudinal study		Yes	Psychological changes	Emotional Responses of Athletes to Injury Questionnaire (ERAIQ) and ACL-Return to Sport after Injury Scale (ACL-RSI)	Psychological responses of patients changed over time during the rehabilitation. As rehabilitation progressed, negative emotions of patients decreased, as the feeling about returning to sport [illegible]

						revealed there were significant differences in psychological readiness between the participants who did and did not return to sport. Participants who had returned to sport had more positive attitudes during the season at 6 and 12 months following surgery
Behaviour						
Brewer et al. (2004)[?]	108, Male and female, 29.38 years, Correlational design		Yes	Demographic, injury related, adherence, and rehabilitation outcome variables	Questionnaire, self-report, adherence, Knee Outcome Survey – Sports Activities Scale (KOS-SAS)	Adherence to home-based rehabilitation activities are of importance for the outcome of the ACL reconstruction. The positive relationship between adherence and outcome exists for the outcome variable self-reported physical symptoms
Carson & Polman (2010)[?]	4, Male, 19-27 years, Multiple case study	Rugby	Yes	Avoidance coping	Interviews, self-report diary and Coping with Health, Injuries and Problems (CHIP) inventory	Avoidance coping can be beneficial in the rehabilitation process to [illegible] short-term emotional states, but can also have long-term benefits
Scherzer et al. (2001)[?]	54, Male and female, 28 years (9.33), Prospective correlational design		Yes	Relation between psychological skills (goal setting, healing imagery and positive self-talk) and adherence	Sports Injury Survey, Sports Injury Rehabilitation Adherence Scale	Goal setting can have a positive effect on sports injury rehabilitation adherence. Positive self-talk was positively correlated with adherence to home rehabilitation exercises
Outcome						
[illegible] et al. (2004)	-, Review			Return to play	Literature search	63% - 92% of the patients were able to return to their pre-injury sports activity level
Gobbi & Francisco (2006)	100, Male and female, 28 years (17-50), Prospective cohort study	Soccer, skiing, running, motocross, volleyball, [illegible], basketball, tennis, skiing, soccer, tennis, volleyball, baseball, rugby, karate, cycling, swimming, [illegible], wrestling and gymnastics	Yes	Return to sport	Psychovitality questionnaire (psychovitality)	65% of the athletes returned to their sports at equal following ACL reconstruction. The athlete's psychological profile was an additional factor that determined which patients have a greater chance of returning to their pre-injury levels

[illegible] et al. (2008)	84, Male and female, 24.8 years (18-40), Cohort study		Yes	Return to sport	[illegible] Knee [illegible] activity and Subjective International Knee Documentation Committee (IKDC) questionnaire	67% of the patients returned to their [illegible] [illegible] was an [illegible] psychological factor for patients who did not return to their sport. [illegible] returning to their [illegible] was having an [illegible]
[illegible] et al. (2010)	49 Case series	Football	Yes	Return to play	Historical and current player database of National Football League (NFL)	63% of the athletes returned to NFL game play at an average of 10.8 months after surgery. More experienced and [illegible] athletes are more likely to return to [illegible] at the same level after [illegible] than those with less [illegible] experience
[illegible] & [illegible]	46, Male and female		Mixed	Personality traits	[illegible] scales of Personality	Patients with [illegible]

(2008)	32 years (18-51), Prospective study				(SSP), KOOS	[illegible] were [illegible] than those who [illegible] [illegible] scale [illegible] scored [illegible] the KOOS
[illegible] et al. (2012)	49, Male and female, 24.1 years (17-52), Correlational design	Soccer, basketball, hockey, skiing, football, squash, karate, rugby, volleyball and [illegible]	Yes	Fear of re-injury, negative affect, pain catastrophizing, return to sport	[illegible] Scale for Kinesiophobia [illegible] Mood States (POMS), Pain Catastrophizing Scale (PCS), Sport Self-Confidence Inventory	All [illegible] [illegible] those with greater negative mood and greater fear of re-injury were [illegible] to return to sporting activity
Interventions						
[illegible] & Brewer (2011)	30, Male and female, 28.? years (18-5?), Randomised controlled trial	Basketball, [illegible], skiing, soccer, [illegible], hockey [illegible] and other activities	Yes	Relaxation and Guided imagery	[illegible]	Relaxation and imagery-based psychological intervention was found to be effective in [illegible] recovery following ACL [illegible] [illegible] significantly greater knee strength and significantly lower

						[illegible] of re-injury anxiety and pain
Maddison et al. (2006)[illegible]	58, Male and female, 18-55 years, Randomised controlled study	Rugby, [illegible]	Yes	Anxiety, pain and self-efficacy	[illegible] perceptions of expected pain [illegible] scale ranging from 0-100 [illegible] Activity Scale [illegible] Activity Inventory (STAI) Self-efficacy [illegible] scale, [illegible] walking self-efficacy (WSE) scale	Watching a modelling video may be an effective [illegible] perceptions of expected pain and [illegible] rehabilitation self-efficacy
Mankad et al. (2009)[illegible]	15, Male and female, 21-58 years [illegible], [illegible] study	Rugby, Australian football and basketball	Yes	[illegible]	[illegible] Event Scale [illegible] Profile of Mood States (A-POMS)	[illegible]
Myers et al. (2004)[illegible]	40 [illegible] study		No	[illegible] Scale imagery [illegible] goal setting strategies [illegible]	[illegible] Questionnaire	[illegible]
				Relationship between [illegible]		There was a significant positive relationship between [illegible]
[illegible] (2002)	3, Male and female, [illegible] years, [illegible]	[illegible]	Yes	[illegible] skills [illegible]	[illegible] Survey [illegible] Rehabilitation Adherence Scale [illegible] of Athletes Injury Questionnaire [illegible] reports	There is some evidence for the [illegible] psychological [illegible]
[illegible] et al. (2013)	24, Male and female, [illegible] years [illegible], Randomised controlled study		No	[illegible] self-efficacy	Knee Self-efficacy Scale (K-SES), [illegible] Activity Scale, Physical Activity Scale (PAS), Knee injury and Osteoarthritis Outcome Score (KOOS) and Mental [illegible] (MHLC)	There is [illegible] self-efficacy [illegible]

Cognition

The first part of the biopsychosocial model, as shown in figure 7.1, consists of cognition. According to Wiese-Bjornstal (2010), cognition includes the thoughts that athletes experience after an injury[5]. One of these cognitive factors involved with rehabilitation of ACL injury followed by reconstruction is internal Health Locus of Control (HLOC). This was studied by Nyland et al. (2006)[8]. HLOC is the degree to which individuals perceive their ability to control life events. Persons with a high internal HLOC experience life events as being a consequence of one's own personal actions. Likewise, persons with a low internal (more external) HLOC consider these events more as fate or chance, i.e., something that they cannot exert any control of. The main result of this study performed by Nyland et al. (2006) was that persons with a high internal HLOC were more satisfied with their knee function (measured by Knee Outcome Survey), their activities of daily living (measured by the Activities of Daily Living Scale), and their sports activities after ACL reconstruction (measured by Sports Activity Scale) compared with athletes with a low internal (more external) HLOC[8].

With regard to self-efficacy, Thomeé and his colleagues performed three studies about this cognitive factor[9-11]. Self-efficacy refers to the judgment of a person's ability to perform a task, rather than whether he or she can actually do it[10]. First of all, Thomeé et al. (2007a) suggested that the internal locus of control and the way the patient felt about the knee function in sports and recreation activities were the best predictors of self-efficacy[9]. With this in mind, they concluded in their second study that patients' activities and their perceived self-efficacy increased during the rehabilitation process. However, being male, young, and more physically active preoperatively appeared to be favorable factors for a higher self-efficacy score[11]. Thomeé et al. (2007c) demonstrated also that patients' preoperative self-efficacy of knee function can predict the patients' outcome in terms of physical activity, knee symptoms, and muscle function 1 year after an ACL reconstruction[11]. Thomeé and colleagues give evidence for the fact that having more self-efficacy is beneficial for the rehabilitation process following ACL reconstruction.

Based on these four articles about cognitive factors, we can conclude that having a high internal HLOC and more self-efficacy preoperatively can improve the outcome after an ACL injury followed by a reconstruction.

Affect

The affective responses concern the way athletes feel after an injury. Injuries can lead to major psychosocial changes, which have an influence on the rehabilitation process. Athletes with an ACL reconstruction experienced fewer negative emotions, felt more positive about returning to sport, and experienced less pain, as time progressed since surgery[12,13,16]. Negative mood and pain could be predicted by both personal variables (athletic identity, neuroticism, and optimism) and situational variables (perceived daily stress and physical activity)[12]. The decline in negative mood during the rehabilitation process was stronger in patients high in athletic identity and low in optimism. A possible explanation for this last finding is that athletes low in optimism had a more negative mood at the beginning of the rehabilitation process than athletes high in optimism. However, the group low in optimism but high in athletic identity had a stronger decline in negative mood during the rehabilitation process (than athletes low in optimism and low in athletic identity). The pain experiences of patients decreased when time progressed since surgery, but the degree of decrease was less over time. Significant differences in psychosocial responses were found in those who did and did not return to sport after injury. Athletes who had more doubts about returning to sport returned less often to their sport compared with athletes who experienced less doubts[16].

Fear of reinjury is a factor that has a negative influence on the rehabilitation of an ACL injury followed by a reconstruction. Fear of reinjury, as well as a worse knee-related quality of life, was considered as a hindrance for returning to sport[13-15]. Furthermore, fear of reinjury consists of concerns about the inability to return to preinjury sport/activity levels and possible functional impairments[13,14]. The rate of fear of reinjury was highest in periods when patients tried to return to sports activities[13]. The results of Heijne et al. (2008) showed that all participants had a fear of going back to the sports they performed before the ACL injury[14]. In their study, they interviewed 10 patients about their experiences during the rehabilitation period. Besides fear of reinjury, all patients became frustrated because the recovery of the ACL injury and surgery took longer than expected. As a result of this, individuals lost confidence in their rehabilitation process and self-esteem.

Together, these studies showed that there were positive psychosocial changes as rehabilitation progressed, i.e., fewer negative emotions, more positive feelings about returning to sport, and less pain. However, individuals experienced a fear of reinjury that had a negative influence on their rehabilitation process.

Behavior

In the context of rehabilitation following an ACL injury and reconstruction, the behaviors reviewed here were avoidance coping and rehabilitation adherence. Avoidance coping can be divided into two different types: behavioral avoidance coping, which was defined as "the conscious decision to remove oneself from a threatening environment," and cognitive avoidance coping, which was defined as "the responses aimed at denying or minimizing the seriousness of a crisis or its consequences"[18]. The four professional rugby players in the study of Carson and Polman (2010) used both behavioral and cognitive avoidance coping strategies in their rehabilitation process[18]. The interviews with these rugby players showed that these coping strategies were useful for the recovery of their ACL injury and reconstruction in both short term and long term.

Another behavior that is of important value in recovering from ACL injury and reconstruction is adherence to the rehabilitation program. Adherence to clinic-based activity was strongly related to the outcome compared with adherence to home exercises[17]. Patients who had a higher score for adherence experienced fewer knee symptoms, suggesting that adherence to the rehabilitation program has a positive effect on the recovery from the ACL injury and reconstruction. Setting goals had a beneficial effect on both rehabilitation adherences (rehabilitation sessions and home rehabilitation exercises). In addition, positive self-talk appeared to have a positive correlation with adherence to home rehabilitation exercises[19].

The abovementioned studies indicate that the behavior of individuals with an ACL injury could influence the outcome of the recovery. This recovery is positively reinforced when someone pays attention to alternative goals and follows all the exercises and training sessions imposed by the trainer or physiotherapist.

Outcome

A measure for the success of recovery from an ACL injury and reconstruction is often represented by whether or not someone gets back to their pre-injury sports activity level. This is indicated by the term "return to play" or "return to sport." Studies included in this review showed that 41-92% of the athletes returned to their previous level of sport[20-23]. A significant amount of athletes failed to return to sports because of fear of reinjury, pain related to chondropathy, and having an unstable knee. According to Gobbi and Francisco (2006), there were significant differences between those who did and did not return to sport[21]. The first group had better scores on the Marx scale (knee activity rating scale) and the Psychovitality Questionnaire, and experienced less fear of reinjury and less negative affect[22,25]. Athletes who did return to sports were also more experienced, i.e., played more than 4 years in the National Football League, and more established athletes. Less-experienced athletes had a lower rate of return to sports probably due to the fact that they had poorer facilities[23]. Another study with regard to the outcome of the ACL injury and reconstruction was performed by Swirtun and Renström (2008)[24]. They demonstrated that personality traits had an influence on the outcome of the ACL injury recovery period. Individuals who had fewer problems in the pain and symptom subscores were lower in embitterment than persons who had more problems in these subscales.

In conclusion, after having an ACL injury, whether or not reconstructive surgery is performed, not all athletes returned to sports. One of the main reasons for not returning back is fear of reinjury. Other reasons could be pain and having an unstable knee.

Psychosocial interventions

With the aim to improve the recovery of patients with an ACL injury, whether or not reconstructive surgery is performed, researchers have evaluated interventions that could be beneficial for the rehabilitation. Cupal and Brewer (2001) investigated whether relaxation and guided imagery had any effect on knee strength, reinjury anxiety, and pain after a reconstruction of the ACL[26].

Three different groups (treatment, placebo, and control) were compared with each other. The treatment consisted of 10 individual sessions of relaxation and guided imagery. Besides this intervention, these individuals followed normal physical therapy according to the sports medicine facility's protocol for physical therapy after ACL reconstruction. Participants in the placebo group followed also normal physical therapy, with the addition of attention, encouragement, and support from the clinician. Individuals of the control group followed only normal physical therapy with no additions. The hypothesis that participants from the treatment group (i.e., inclusive sessions of relaxation and guided imagery) had greater knee strength, less reinjury anxiety, and less pain compared with the placebo and control group was confirmed.

With regard to increasing self-efficacy following ACL injury and reconstruction, modeling and specific training for improving patients' self-efficacy appeared to be useful[27,31]. According to Maddison et al. (2006), modeling could reduce the perception of pain and anxiety of a person and increase the self-efficacy during the rehabilitation of ACL reconstruction[27]. Participants were divided into two groups: 30 participants were randomly assigned to the intervention group and 28 participants were assigned to the control group. The persons of the intervention group viewed two coping model videos. Results showed that there was a significant effect for perception of expected pain; individuals who watched the videos reported less pain. The modeling video was useful for increasing self-efficacy early in rehabilitation. Thus, persons who watched the videos perceived less pain and had more self-efficacy than persons of the control group. In a research of Thomeé et al. (2010), all patients underwent a standardized rehabilitation program but they were divided into two different groups[31]. There were two differences between the experimental (n=12) and the control group (n=12). The participants of the experimental group received specific training to enhance their self-efficacy based on a clinical model, and the physiotherapists treating these patients gave them their self-efficacy scores. The clinical model consisted of four different phases (understanding, maturity, persistence, and coping), which physiotherapists used to exert a positive influence on the patients, and in this way increasing their self-efficacy. Using this model, physiotherapists attempt to provide the patients more information about their injury, the rehabilitation process, setting goals, and performing exercises regarding the recovery. The researchers concluded, in contrast with the hypothesis, that patients with an ACL injury who received strategies to enhance self-efficacy had no better outcome than patients of the control group. This indicates that the clinical rehabilitation model used in this study of Thomeé et al. (2010) is unable to increase self-efficacy of patients with an ACL injury[31].

Athletes with an ACL injury, whether or not reconstructive surgery is performed, often inhibit negative emotions due to their injury. An intervention that tried to prevent this consists of writing about the trauma, i.e., a written disclosure intervention[28]. This study of Mankad et al. (2009) showed that emotional disclosure during recovery could have positive effects on injured athletes, because it caused a reduction of stress and total mood disturbances.

Myers et al. (2004) investigated the treatment acceptability in football players[29]. Players were asked to assess two different psychosocial treatments for the recovery of an ACL injury. The behavior treatment consists of positive self-talk, imagery, relaxation training, and goal setting strategies, and the counseling treatment was focused on the relationship between the counselor and the player, a general feeling of acceptance and increasing emotional awareness and resulting catharsis. Counseling skills had an influence on components of social support. For example, it provided emotional support and helped patients cope with negative feelings (listening support)[30]. In the study of Myers et al. (2004) there was a relation between the years of football experiences and the acceptability of the behavioral treatment (the experienced players were more open to the behavioral treatment than less-experienced players)[29]. Furthermore, both treatments were considered as moderately acceptable. The latter finding is relevant for practice because the authors assumed a relation among the acceptability, treatment adherence, and resulting efficacy. Rock and Jones (2002) determined that interventions with counseling skills were useful for the rehabilitation of an ACL injury and surgery in terms of emotional, listening, and informational support[30]. This social support has in turn a positive influence on the adherence to rehabilitation. Furthermore, counseling skills interventions might be useful for coping with setbacks during rehabilitation.

In conclusion, psychosocial interventions, such as relaxation, imagery, training of self-efficacy, and modeling, were advantageous in facilitating the rehabilitation of an ACL injury whether or not reconstructive surgery is performed.

Discussion

An ACL injury can have major consequences for the development of further sports activities. Besides the physical recovery of the knee, the psychosocial aspect of rehabilitation receives increasing attention in literature. The purpose of this review was to give an overview of literature of the psychosocial factors that have an effect on the recovery of ACL injury and reconstructive surgery in athletes. The biopsychosocial model of Wiese-Bjornstal (figure 7.1) was used as a basic framework and all aspects of this model are interrelated and influencing each other[5]. Besides the four components of this original biopsychosocial model, our results showed that interventions also have an important role with regard to the rehabilitation of ACL injury and reconstructive surgery. So, to optimize the original model, we propose to add the factor psychosocial interventions. These interventions appeared to have an influence on the cognition and affect parts of the original model. These two parts in turn had an influence on the behavior of athletes with an ACL injury, and this is affecting the outcome of the recovery. An example of the multiple interactions in this model is represented as follows: Maddison et al. (2006) showed that watching a modeling video (intervention) led to more self-efficacy (cognition)[27]. Patients with more self-efficacy have more confidence in their rehabilitation process and experience less fear of reinjury (affect). This latter is in turn favorable for returning to sports after the injury (outcome). The four components of the original model will be discussed separately in the next sections. As we suggest psychosocial interventions as a fifth part of the model, these interventions will be addressed in each of the following: cognition, affect, behavior, and outcome sections.

Cognition

Based on the articles about cognitive factors, we can conclude that having a high internal HLOC and a high self-efficacy score preoperatively could improve the outcome after an ACL reconstruction[8-11]. This is not surprising because both factors concern the confidence of a person in its own qualities. Having confidence in the rehabilitation of the knee injury facilitates a positive outcome. Patients with more self-efficacy perceive the outcome of the rehabilitation process as a result of their own behavior, i.e., they have a higher internal locus of control compared with patients with less self-efficacy[9]. Because of the fact that self-efficacy appeared to have a significant value in the outcome of the rehabilitation process, several researchers developed psychosocial interventions for improving this self-efficacy. According to Maddison et al. (2006), watching a modeling video is a successful intervention for the recovery of an ACL injury and reconstructive surgery[27]. Because of this modeling video, patients' self-efficacy will increase, which in turn will lead to less pain because there is a negative correlation between these two cognitive factors[32]. So, watching a modeling video could be a useful addition of existing rehabilitation programs.

Affect

Athletes perceive, especially in the initial phase after the onset of the injury, negative thoughts and depressed feelings[33]. These emotional experiences consist particularly of anxiety, fear, anger, confusion, and frustration[14,34]. These emotions were also reflected in the biopsychosocial model of Wiese-Bjornstal, and studies have shown that these feelings change over time[16]. For example, pain and negative mood decreased when rehabilitation progressed, which is beneficial for the recovery[12,13,16]. The decrease in negative mood appeared to be strongest in patients who had a high level of athletic identity[12]. Individuals with a high level of athletic identity perceived dealing with stressful events, such as recovering from an injury, as a task that belongs to athletes. This ensures that athletes with a high level of athletic identity were more emotionally resilient, which is advantageous for recovering of an ACL injury and reconstructive surgery[12,33].

Another emotion that appeared in the rehabilitation context is frustration. Patients with an ACL injury mentioned that their rehabilitation period lasted longer than they previously expected. Because of this, feelings of frustration, and lost of confidence in the recovery and in their self-esteem emerged[14]. To prevent this feeling of frustration, therapists should preoperatively meet the patients to ensure a more realistic view of what the patients have to expect after surgery[20]. Likewise, interventions that contain counseling skills appeared to be useful for the rehabilitation of an ACL injury and should be applied by the treatment team of an athlete with ACL injury. By this, patients experienced emotional, listening, and informational support that makes them better in assessing the progress of their recovery and get less frustrated[30]. This social support is in more ways important for the recovery of the knee injury because it had a positive influence on the adherence to rehabilitation[30]. Rock and Jones (2002) suggested that an increase in social support through the use of counseling skills led to an increase in adherence to rehabilitation. Another positive relation regarding adherence was found between positive self-talk and adherence[17,19] and between setting goals and rehabilitation adherence[14,19]. By setting goals (cognition), athletes were more directed to their rehabilitation program, leading to a better adherence (behavior) and a better outcome of the knee. This is an example of the interactions between the several aspects of the biopsychosocial model we used in this review. The recommendation for those treating athletes with an ACL injury is to encourage these patients to use positive self-talk and set achievable goals for themselves.

Athletes often inhibit all those abovementioned emotions during their rehabilitation. Mankad et al. (2009) hypothesized that writing about injury-related emotions, i.e., disclosing the emotions, could be beneficial for the rehabilitation process of patients who underwent an ACL reconstruction[28]. Results showed indeed reduced stress levels and less mood disturbance after athletes had undergone this intervention. Another outcome was the common use of suppressive coping strategies among the participants, which they used to maintain a positive appearance to their environment, even though they experienced emotional distress. So, writing about emotions during the recovery period is another potential intervention that could be useful for athletes with an ACL injury.

Behavior

In line with coping strategies, Carson and Polman (2010) showed that behavioral as well as cognitive avoidance coping strategies were used equally by the professional rugby players in this study, and that these strategies had positive short- and long-term effects[18]. A common type of strategy was the use of both behavioral (e.g., performing a new hobby) and cognitive (e.g., refusing to watch games) distraction coping. Furthermore, each player indicated the need to dissociate themselves from the whole situation, so the player could manage stressful, uncontrollable situations. Despite the beneficial effect of avoidance coping strategies, athletes should be aware of the negative effects of these strategies when used excessively, for example, when there is too much deviation from his or her normal lifestyle.

Outcome

Fear of reinjury was the most common cause in athletes with an ACL injury and reconstructive surgery who failed to return to sports[13,15,21,22,25]. Remarkable was

that none of the 10 participants of the study of Tracey (2003) experienced a fear of reinjury[33]. These athletes indicated that they were more concerned about healing and return to sports participation than about the possibility of reinjury. They experienced rather other fears, such as fear of loss of independence, fear of asking for assistance, and fear of losing a spot in the team. The differences between the results of Tracey (2003) and other studies may be due to the instrument used. Tracey determined the fear of reinjury by conducting interviews[33], while other studies, with the exception of Heijne et al. (2008)[14], used the Tampa Scale of Kinesiophobia, which has proved to be valid and reliable. The rate of fear of reinjury appeared to be dependent on the time after surgery and the level of optimism[12,13]. Fear of reinjury decreased with time after surgery and was associated with function of the knee, only in the period when patients were returning to sports[13,33]. One of the articles about interventions made a suggestion for therapists to reduce the fear of reinjury[26]. These researchers showed a significant lower level of reinjury anxiety among athletes due to the relaxation and imagery sessions.

This review tried to give an overview of literature of the psychosocial factors that have an effect on the recovery of ACL injury and reconstructive surgery in athletes. As expected, cognition, affect, behavior, and outcome were all influenced by each other. For example, athletes with a low level of optimism (cognition) were more afraid of getting reinjured (affect), which caused a lower rate of returning to their sports (outcome). Furthermore, possible interventions were shown to improve these psychosocial factors in order to facilitate the rehabilitation. After evaluating these interventions, we can conclude that psychosocial factors that had an influence on the recovery could be positively affected by interventions. Though, further research should be done to optimize the effectiveness of these interventions and to determine how these interventions can be applied in already existing rehabilitation programs. In any case, it is clear that the psychosocial recovery of an ACL injury and reconstructive surgery is of very important value.

Perspectives

To ensure a good recovery of ACL injury and reconstructive surgery in athletes, it is important to understand the factors that are related to this rehabilitation process. The model of Wiese-Bjornstal (2010)[5] appeared to be a good starting point, because it shows that cognition, affect, behavior, and outcome are related with each other and thus have all an influence on the recovery of an ACL injury. The information in this review may be important for rehabilitation specialists, who help athletes to recover from ACL injury and reconstructive surgery. With regard to the variables mentioned in this review, they could design and apply interventions in rehabilitation settings to make sure an athlete recovers well from his or her ACL injury. Especially for athletes, a quick and successful recovery (i.e., return to pre-injury level) is important to limit all the negative consequences of the injury and to make sure that athletes can train and play full-time as soon and safely as possible.

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Chapter 8

General discussion

The studies in this thesis investigated the performance development of talented youth male basketball players (aged 13-19) aiming to achieve the elite level in adulthood. The data provide unique information about the performance development of players of different positions in different age categories. The results of the studies indicate the value of monitoring the development of basketball players in a multidimensional and longitudinal way, with an individual focus. The main results of the studies are discussed below.

The importance of maturity timing and height

Results of this thesis revealed that Dutch basketball players who were selected for the talent development program matured earlier and were taller compared to their peers (chapter 2). The players in this study grew on average from 1.70 ± 0.12 m at age 13, to 1.87 ± 0.07 m at age 16, up to 1.90 ± 0.09 m at age 19, which is similar to the height of basketball players in other studies[1-3]. Players of this thesis reached their peak height velocity at a mean age of 13.06 ± 0.77 years, which is earlier than typically developing boys who, according to reference values of the population, experience their highest velocity of growth at the average age of 14 years[2,4]. In chapter 2 and 6 findings on maturity and height differences based on player's position were reported, with centers maturing earliest and being the tallest players followed by forwards and guards. These differences are in accordance with literature[5-7]. More interesting, results of chapter 6 indicated the overall importance of height in basketball by showing that within each position players who achieved the elite level of performance were taller compared to their colleague basketball players who did not achieve the elite level.

Considering the explicit and implicit game components of basketball, i.e., the basket located at 3.05 m, and the positional roles within a team, it is plausible that being tall is an advantage to perform well, especially for center position players. However, coaches, trainers, and scouts should be careful not to emphasize height of youth players too much, since there are considerable interindividual differences and players are not fully matured until they reach the age of approximately 16 years[4,8]. Recent research of Torres-Unda et al. (2015) also confirmed that maturity status may be a very important factor in the performance of elite adolescent basketball players[10]. Players who mature late (and who are thus temporarily smaller than their colleague basketball players) may be overlooked due to their temporary smaller stature. As a consequence, these players may not be provided with the same opportunities (i.e., RTC selection team environment) to optimize their performance, despite that differences in capability attributable to differing timing and tempo of maturity may disappear once players have fully matured[4,9,10].

Another consequence of the strong emphasis on height is that it might discourage smaller children to choose basketball as their sport. This is indicated by the relatively low participation rate of youngsters in competitive basketball[11]. A study with French youth basketball players showed an overrepresentation of dropouts among players aged 9-15 years born in the third and fourth quarter of the year. Due to the birth date of these children relative to the timing of the basketball season (i.e., cut-off date for youth competitions being 1st of January), these children are likely to be (temporarily) smaller and less physical developed compared to their colleague basketball players born in the first and second quarter of the year[12]. Smaller players are likely to have compromised ability perceptions and to lose fun and motivation as they have to compete against taller and stronger players, which can ultimately result in dropout[12-15].

In order to prevent talented players from being overlooked, and to increase the participation rate and decrease the dropouts, it might be useful to reduce the emphasis on players' height in youth basketball. One strategy to achieve this is to use body-scaled equipment, for example by different heights of the basket for youth players aged 12-16 years. Affordances, i.e., opportunities for actions, that are body-scaled enhance technical and tactical skill acquisition and are likely to increase fun and motivation[16-21]. There are already some adjustments in the basketball game for younger players in the Dutch basketball competition (< 12 years), for example the basket located at 2.60 m[22]. However, most youth's bodies are not fully matured until the age of 16[4,8]. Children between the age of 12 and 16 are therefore highly vulnerable to the effects of maturation[4]. It is, as a consequence, suggested to adjust the height of the basket to players' height till the age of 16 (i.e., adjusting the explicit game component). Anthropometrical differences between children and adults can be used as a rationale to scale the height of the basket. The average height of a Dutch adult man is 1.85 m and the basket in the Dutch competition is located at 3.05 m[23]. This means a ratio of approximately 1 to 1.65 for adult players. Dutch males aged 12-13 (U14) and 14-15 (U16) are on average 1.59 m and 1.72 m, which indicates the basket at a height of 2.62 m and 2.84 m, respectively[24]. According to this ratio, the basket for U12 should be located at 2.43 m (i.e., the average height of Dutch males aged 10-11 is 1.47 m). It is suggested to play with the basket located at 3.05 m from 16 years onwards, to deal with the explicit game components as played in adult basketball.

In conclusion, height plays a major role in youth basketball. Differences in maturation and height have been identified between players participating in this thesis and their peers, and between players of this thesis of different playing positions. It is suggested to reduce this emphasis on height in youth by using different heights of the basket for players of the U12 (2.43 m), U14 (2.62 m) and U16 (2.84 m) team. This adjustment aims to counteract the benefits from being (very) tall, and as such to prevent talented players who mature later from being overlooked. Players will also be stimulated and challenged to practice other, more trainable basketball-related performance skills (e.g., technical skills). In addition, the decreased emphasis on height might encourage more children to play basketball. All these possible positive effects might in turn increase the level of basketball performance in the Netherlands in the long-term by creating a larger pool of basketball players to choose from when identifying talented players.

Development of physiological and technical skills and the role of reflection

In order to achieve the elite level of performance, players should be aware of the requirements of the basketball game which are necessary to achieve this ultimate goal[25]. These requirements differ slightly between players of the guard, forward, and center position since these positions all have different tasks within a team[26]. For example, guards need to start the offence during a game and need to get past their opponents. Repeated sprint, change-of-direction speed and ball control can therefore, among others, be considered as position-related characteristics for guards (chapter 6). Results of chapters 3 and 4 revealed a performance improvement of these skills over time. The increase in repeated sprint ability was most evident from the age of 14 (26.09 ± 0.94 s) through 17 (25.18 ± 0.97 s; improvement of 3.49%), with a slowing rate of increase until age 19 (24.82 ± 1.04 s; another 1.43 % improvement) (chapter 3). For change-of-direction speed, it was found that players aged 18-19 (18.00 ± 0.78 s) were significantly better (i.e., faster on the STARtest without ball) compared to 14-15 year old players (19.06 ± 1.05 s) (chapter 4). Results of this chapter also showed an improvement in ball control over time, with players aged 16-17 (19.45 ± 1.06 s) and 18-19 (19.03 ± 0.94 s) being significantly faster on the STARtest with ball compared to 14-15 year old players (20.48 ± 1.25 s). Moreover, the largest improvement in ball control was found for guard position players, suggesting the importance of ball control especially for these players (chapter 5).

The performance development is caused by, among others, the effects of maturation and the number of training hours. However, the efficiency of training hours, and therewith reflective skills of players, may be even more important in order to improve basketball-related skills[27-30]. To derive most from training hours reflective skills, i.e., the capability to appraise previous performance to improve future performance, are of utmost importance[27-30]. In chapter 5 it was revealed that reflective skills of talented youth basketball players, as measured with the self-regulation of learning self-report scale (SRL-SRS), do not develop over time but are highly important in achieving the elite level of performance. Results of this chapter showed a high score on reflection (4.03 ± 0.54) for the total group, and an even higher score (4.29 ± 0.29) for players who attained the elite level of performance in adulthood (range 1-5). These scores were similar to the results of other research in a variety of sports[30-32], and strengthen the idea that reflection is important in order to achieve the elite level of performance.

As suggested in chapter 5, reflective skills are thought to be most useful when players apply these skills in order to achieve a specific goal (i.e., improve their basketball-related skills). For example, a player predefines a goal related to the improvement of his repeated sprint ability. This player consequently needs to make a plan on how to reach this goal, and needs to reflect continuously on his repeated sprint ability in order to improve this skill. Previous research has demonstrated that coaches and trainers are in a position to increase the use of reflection among talented athletes. For example by helping athletes to make effective judgments about their performance, compare performance to the predefined goals, and helping athletes to identify points for improvement[33,34].

Both the study by Collins et al. (2014) and Faull et al. (2009) showed that talented athletes who are aiming to achieve the elite level of performance can increase their use of reflective skills, which may ultimately result in increased performance[33,34].

It can be concluded that each playing position has slightly different requirements in order to perform well during a basketball game. However, reflection can be considered as an important skill for talented youth basketball players of all playing positions, aiming to attain the elite level of performance in adulthood. Using these reflective skills in order to improve other basketball-related skills is thought to be helpful in achieving the elite level.

Towards individual profiles

For basketball players who spend many hours in training to improve their skills, it is important to measure and monitor their performance to gain insight into their development. As suggested by literature and the research presented in this thesis, players should be monitored structurally in order to measure progression rather than assessing performance at a single occasion[35]. The studies presented in this thesis showed outcomes applicable for the total group of players (e.g., chapter 5), as well as outcomes distinguished by age categories (e.g., chapter 3), positions (e.g., chapter 2), and individual differences (chapter 6). Players might show weaknesses in one skill, but may excel in others, which is known as the compensation effect[35]. Chapter 6 has shown that players who achieved the elite level differ during their development in their anthropometrical, physiological, technical, and psychosocial characteristics. This indicates that the combination of characteristics necessary for achieving the elite level might be different for individual players. Therefore, individual profiling in a multidimensional and longitudinal approach seems valuable[36-39].

However, applying this individual focus in science is a considerable challenge. Science is characterized by universal laws in which researchers strive to find regularities or patterns that can be applied to a whole population[40]. Nevertheless, experts in sports (or other domains like music and education) are individuals who do not comply with regularities. Rather, their performance can be considered as outliers which might suggest a need for other methodological approaches to study expertise, such as applied in chapter 6.

In conclusion, performance-related differences between age categories, positions, and individual players were identified in the studies of this thesis. These individual differences were also evident in the development towards the elite level of performance in adulthood. Therefore, a focus on individual profiling is recommended within the multidimensional and longitudinal research on talent development.

Limitations and recommendations for future research

The conclusions in this thesis are based on data obtained with frequently used and feasible methods of which reliability and/or validity has been confirmed.

However, caution is required when interpreting the results since there are some limitations associated with these methods. The formula of Mirwald et al. (2002)[41] to estimate players' age at peak height velocity, for example, is less applicable to early maturing players compared to average maturing boys, and is still being discussed in literature[8,42]. Nevertheless, due to its practical feasibility and the lack of other suitable non-invasive methods, this formula is still used in research related to young athletes[43].

This thesis applied a multidimensional and longitudinal approach in which different characteristics were investigated to obtain a holistic overview of the performance development of players. However, one should be aware of other characteristics that also might have an effect on the performance development of talented basketball players. Tactical characteristics, for example, belong as well to the multidimensional performance characteristics related to basketball, and have been proven to play an important role within team sports performances[44,45]. Due to practical reasons, tactical characteristics were not included in this thesis. Another important aspect to take into account when considering the development of talented youth players are injuries. As shown in our review (chapter 7), injuries hinder the development of basketball players. Despite that we provided an overview of the literature related to the recovery process of injuries, we were unable to monitor the frequency and duration of the injuries sustained by players investigated in this thesis. Especially in view of the age range of our target group, it is recommended to take into account the effects of injuries on the development of players in future research. Considering the vast number of factors influencing talent development, the challenge is to approach the development of talented basketball players in a manner that is as inclusive as possible[46].

A last remark that should be made refers to the elite level of performance as specified in the studies of this thesis. The elite level of performance was defined as playing at the highest competition level in the Netherlands (Eredivisie). Despite that it is an excellent achievement when players attain this level, it should be noted that the elite level in the Netherlands is relatively low compared to the elite level of basketball in other countries, such as in the USA[47]. Reference values as shown in this thesis may as a consequence be representative for Dutch basketball players. It is, therefore, suggested that coaches and trainers develop reference curves for the performance of their own players.

Recommendations for basketball practice

The results of this thesis indicate the value of monitoring the performance development of talented youth basketball players in a multidimensional and longitudinal manner, with an individual focus. Although further research is needed to unravel the development of talented youth players towards the elite level even more, this thesis has revealed a number of recommendations for coaches, trainers, scouts, and policy makers involved in youth basketball:

- *Adjust the height of the basket according to the height of players (body-scaled) in the U12 (2.43 m), U14 (2.62 m), and U16 (2.84 m) teams.* This might reduce the emphasis on height in youth basketball. It might prevent late maturing players from being overlooked, challenge early maturing players more, and it will encourage players to practice basketball-related skills that are trainable (e.g., physiological and technical skills). Furthermore, the decreased emphasis on height is likely to increase the fun and motivation of young players, and as a consequence improve the participation rate and reduce the number of dropouts. Ultimately, this may increase the level of basketball performance in the Netherlands.

- *Stimulate the use of reflective skills of basketball players.* Reflective skills are important for players of all playing positions in order to attain the elite level of performance. Talented youth basketball players are advised to use their reflective skills in order to reach a predefined goal (e.g., improving a basketball-related skill). Coaches and trainers can help players by challenging them to think about their own development. Making the player aware of the requirements that are necessary to reach their goal, and to make an efficient plan to meet this goal may promote players' development of basketball related skills.

- *Monitor multidimensional performance characteristics in a longitudinal manner with an individual focus.* This will provide insight into the individual performance development of talented youth basketball players, to help players in reflecting upon them when working towards their goals. The performance characteristics can be measured at the beginning and end of each season, as demonstrated in the 'Groningen Basketball Test Battery'. Data regarding anthropometrical, physiological, technical, and psychosocial performance characteristics could be recorded to create individual performance profiles of players. Scores within and between seasons could be compared in order to gain insight into the players' development. The individual focus can be applied by using Z-scores and radar graphs when analyzing the data related to the development of players. Coaches and trainers can use the players' performance profile to discuss their development, in order to set short- as well as long-term goals for training and competitions. In addition, the performance profile can be used for players who sustain an injury. After the recovery period, the player can be tested, and results can be compared to scores before the injury in order to determine whether pre-injury levels of performance are reached. More information about the performance characteristics, protocols of the tests, data analysis, interpretation, and reference values can be found in the 'Groningen Basketball Test Battery'.

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Summary

Earlier investigations emphasized the importance of multidimensional and longitudinal research regarding talent development in sports. However, to our knowledge, studies related to the development of talented youth basketball players over the years are scarce. Therefore, the overall aim of this thesis was to gain insight into the performance development of talented youth male basketball players (aged 13 - 19) by adopting a multidimensional and longitudinal approach. Multidimensional performance characteristics (anthropometrical, physiological, technical, psychosocial characteristics) were monitored for five seasons in youth basketball players selected for a talent development program. The total sample included 6448 data points from 99 individual players. These data provided unique information about the performance development of talented basketball players in different age categories who eventually achieved the elite or non-elite level of performance in adulthood.

Chapter 1 described the theoretical background of the studies in this thesis. It stated that the performance development of players is the result of their personal performance characteristics, which are related to the characteristics of the game and influenced by the environment.

The **2nd chapter** investigated the role of maturity timing in selection procedures and in the specialization of playing positions in youth basketball (guard, forward, center). It revealed that basketball players selected for the talent development program were taller and experienced their peak height velocity (PHV) at an earlier age compared to their peers. These results suggest a relation between maturity timing and selection procedures. Furthermore, it has been shown that most players were specialized in one position at an early age and stay at this position during their development. The result of the second part of the study indicated positional differences between guards, forwards, and centers for maturation timing (age at PHV), anthropometrical, physiological and technical performance characteristics. In addition, when statistically controlling for chronological age and age at PHV, it was shown that technical characteristics were least influenced by maturity timing. It was therefore recommended to coaches and trainers of talented youth basketball players to focus more on technical rather than anthropometrical and physiological performance characteristics with regard to selection procedures and the specialization of playing positions.

Given the intermittent character of a basketball game, repeated sprint ability is an important physiological skill for youth basketball players. **Chapter 3** investigated the development of repeated sprint ability in players between 14 and 19 years by using multilevel modeling. Repeated sprint ability improved mostly between 14 and 17 years of age, and reached a plateau at age 17 to 19. Lower body explosive strength and interval endurance capacity appeared to play an important role in order to develop repeated sprint ability. Furthermore, results of this chapter provided age-specific reference values for repeated sprint ability, which may assist coaches and trainers in setting appropriate goals for individual players.

The thesis continued with the investigation of a new basketball-specific test, the STARtest (**chapter 4**). The test was developed to measure change-of-direction speed (performing the test without ball) and ball control (performing the test with ball) of talented youth basketball players. The test consists of basketball-specific movements, i.e., sprinting or dribbling in a forward, backward, and sideward direction. Reproducibility (reliability and agreement) and validity parameters were calculated and showed that the STARtest is a reproducible and valid test. Furthermore, it appeared to be a feasible test which easily can be used by coaches and trainers to monitor change-of-direction speed and ball control of basketball players.

Chapter 5 continued research regarding the STARtest by investigating the importance of ball control and self-regulatory skills (e.g., setting goals, reflecting on one's strengths and weaknesses) in achieving the elite level of performance in basketball. It was shown that reflective skills were most important in order to achieve the elite level of performance. This chapter further aimed to gain insight into the development of, and association between ball control and reflection. The results of multilevel modelling showed no significant improvement in reflection over time for players of guards, forwards, and centers. For ball control, an improvement was evident for guards. Moreover, guards and forwards had better ball control compared to centers. For those two positions, a higher reflection was related to better ball control. This chapter concluded that reflective skills are important for players of all positions to achieve the elite level of performance in adulthood, while ball control is especially important for the guard position players.

The abovementioned multidimensional performance characteristics were all combined in **chapter 6**. The first aim of this study investigated whether it was possible to identify position-related characteristics for players of the guard, forward, and center positions. Results revealed that repeated sprint (best of three), change-of-direction speed, repeated dribble (best of three and total), and ball control were position-related characteristics for guards, while height, wingspan, and effort were position-related characteristics for centers. For forwards, no position-related characteristics could be determined. The second aim was to investigate whether players who attained the elite level performed better during their youth on general basketball-related performance characteristics (i.e., all performance characteristics together) than their peers who did not achieve the elite level. Results confirmed that the elite players had higher levels of performance characteristics during youth compared to their non-elite peers of the same position. In addition, within the second aim it was also investigated whether elite players performed better on position-related skills compared to non-position-related skills. The centers who reached the elite level in adulthood performed better on their position-related skills compared to their non-position-related skills. Finally, the third aim of this study was to investigate possible differences in the development between players who achieved the elite level of performance. Radar graphs of individual players showed individual variations in the development of talented youth players towards elite levels in adulthood, even between players of the same position.

Considering the development of basketball players in a more comprehensive view, the rehabilitation process of injuries was reviewed in **chapter 7**. To minimize the negative influences of injuries on the personal development of players, a successful outcome of the rehabilitation process is important. The chapter aimed to review psychosocial factors that affect the rehabilitation process following anterior cruciate ligament injuries (ACL), which is a common injury in basketball. The systematic search resulted in an overview of psychosocial factors (e.g., goal setting) and interventions (e.g., relaxation and imagery sessions) which could be beneficial for the rehabilitation process, and therefore minimize the negative effects on the performance development of players.

Finally, **chapter 8** provided the general discussion, conclusions, and practical implications for coaches and trainers working with talented youth basketball players. It can be concluded that anthropometrical characteristics develop, and physiological and technical performance characteristics improve over time, while the psychosocial skill reflection stays relatively stable throughout adolescence. The general discussion ended with three recommendations for basketball practice:

- Adjust the height of the basket according to the height of players (body-scaled) in the U12 (2.43 m), U14 (2.62 m), and U16 (2.84 m) teams.

- Stimulate the reflective skills of basketball players, since results of this thesis showed the importance of reflection in achieving the elite level for players of all playing positions.

- Monitor multidimensional performance characteristics in a longitudinal manner with an individual focus in order to take the individual differences between players into account.

Nederlandse samenvatting

Onderzoek naar talentontwikkeling in de sport wordt de laatste jaren steeds vaker gekenmerkt door een multidimensionele en longitudinale benadering. Echter, onderzoek met deze benadering gericht op de ontwikkeling van talentvolle basketballers is beperkt. Dit proefschrift had daarom als doel om via een multidimensionele en longitudinale benadering inzicht te krijgen in de prestatieontwikkeling van talentvolle jonge basketballers in de leeftijd van 13 tot en met 19 jaar. Antropometrische, fysieke, technische en psychosociale kenmerken van basketballers die deel uit maakten van een talentontwikkelingsprogramma (Regionaal Trainingscentrum Noord) zijn gemonitord voor een periode van vijf seizoenen. Een totaal van 6448 datapunten van 99 individuele spelers hebben unieke inzichten gegeven in de prestatieontwikkeling van talentvolle basketballers van verschillende leeftijdscategorieën, waarvan sommigen de top wel en anderen de top niet hebben gehaald op volwassen leeftijd (> 20 jaar in 2014).

In **hoofdstuk 1** is de theoretische achtergrond van de studies in dit proefschrift weergegeven. Hierin werd vermeld dat de prestatieontwikkeling van spelers het resultaat is van hun persoonlijke prestatiekenmerken, welke gerelateerd zijn aan de kenmerken van de taak (het basketbalspel) en welke beïnvloed worden door de omgeving.

In het **2e hoofdstuk** is onderzoek gedaan naar de rol van biologische rijping (groeispurt) in de selectieprocedures voor het talentontwikkelingsprogramma en naar de rol van rijping in het specialiseren in één van de drie posities binnen het basketbal (guard, forward, center). De geselecteerde basketballers waren langer en eerder rijp in vergelijking met hun leeftijdsgenoten. Deze bevindingen suggereerden een relatie tussen het moment van rijping van spelers en de selectieprocedures van het talentontwikkelingsprogramma. Daarnaast is gebleken dat spelers zich al vroeg specialiseren in één van de posities en dat ze gedurende hun jeugd ook vaak op deze positie blijven spelen. De resultaten van het tweede deel van dit hoofdstuk lieten zien dat er positionele verschillen zijn tussen guards, forwards en centers met betrekking tot de biologische rijping, antropometrie en fysieke en technische prestatiekenmerken. Bovendien is er aangetoond dat de technische prestatiekenmerken het minst werden beïnvloed door de rijping van spelers. Er is daarom aan coaches en trainers van talentvolle jeugdige basketballers aangeraden om de nadruk meer op de technische dan op de antropometrische en fysieke prestatiekenmerken te leggen wanneer spelers geselecteerd gaan worden of wanneer spelers zich gaan specialiseren in één van de posities.

Gedurende een basketbalwedstrijd worden intensieve activiteiten (waaronder sprinten en dribbelen) vaak afgewisseld met korte periodes van rust. Door deze kenmerken is het herhaald sprinten een belangrijk aspect voor basketballers. In **hoofdstuk 3** is daarom een studie beschreven waarbij de ontwikkeling van het herhaald sprinten in kaart is gebracht door middel van een multilevel analyse. Zowel de onderliggende factoren als de ontwikkeling van het herhaald sprinten van basketballers in de leeftijd van 14-19 jaar is onderzocht. De explosieve kracht van het onderlichaam en het interval uithoudingsvermogen bleken een belangrijke rol te spelen in de ontwikkeling van het herhaald sprinten. De grootste vooruitgang is gevonden in de leeftijd van 14 tot 17 jaar, gevold door een plateaufase in de ontwikkeling tot 19 jaar. Tot slot zijn er dit hoofdstuk leeftijdsgerelateerde referentiewaarden voor het herhaald sprinten van Nederlandse talentvolle basketballers gegeven welke coaches en trainers kunnen ondersteunen bij het stellen van geschikte doelen voor individuele spelers.

Het proefschrift gaat verder met een onderzoek naar de STARtest; een nieuwe basketbalspecifieke test. De test is ontwikkeld om de behendigheid van spelers met en zonder bal te meten en bestaat uit basketbalspecifieke bewegingen zoals voorwaarts, zijwaarts en achterwaarts sprinten en dribbelen. De resultaten van **hoofdstuk 4** lieten zien dat de STARtest een betrouwbare en valide test is. Daarnaast bleek de test eenvoudig hanteerbaar te zijn voor coaches en trainers om zowel de behendigheid met als zonder bal van jonge basketballers te meten en monitoren.

In **hoofdstuk 5** wordt het onderzoek met behulp van de STARtest vervolgd. Er is onderzoek gedaan naar het belang van een goede behendigheid met bal en het belang van zelfregulatieve kenmerken (reflectie, plannen, evaluatie, monitoren, inzet en het geloof in eigen kunnen) in het behalen van de top in basketbal. De resultaten toonden aan dat reflectie het meest belangrijk is voor basketballers om de top te behalen. Daarnaast is er in deze studie onderzoek gedaan naar de ontwikkeling van, en de samenhang tussen reflectie en behendigheid met bal. Multilevel analyse heeft uitgewezen dat er geen ontwikkeling was van reflectie gedurende de leeftijd van 13 tot 20 jaar. Met betrekking tot de behendigheid van spelers met bal is er een vooruitgang gevonden voor de spelers van de guard positie. Bovendien is er aangetoond dat guards en forwards een betere behendigheid met bal hebben in vergelijking met centers. Voor de eerstgenoemde posities is tevens gebleken dat een hogere mate van reflectie gerelateerd was aan een betere behendigheid met bal. Dit hoofdstuk eindigde met de conclusie dat reflectie een belangrijk kenmerk is voor spelers van alle posities om de top te halen, terwijl behendigheid met bal met name belangrijk is voor spelers van de guard positie.

De bovenstaande multidimensionele prestatiekenmerken worden in het onderzoek van **hoofdstuk 6** samengenomen. Het eerste doel van dit onderzoek was het vaststellen van positiegerelateerde kenmerken voor spelers van de guard, forward en center positie. Het herhaald sprinten (beste van drie), behendigheid zonder bal, herhaald dribbelen (beste van drie en totaal) en behendigheid met bal zijn vastgesteld als positiegerelateerde kenmerken voor guards. Voor spelers van de forward positie konden geen positiegerelateerde kenmerken worden vastgesteld, terwijl lengte, wingspan en inzet positiegerelateerde kenmerken voor centers zijn gebleken. In het tweede gedeelte van de studie is aangetoond dat spelers die de top gehaald hebben, beter scoren op prestatiebepalende kenmerken gedurende hun jeugd dan spelers die de top uiteindelijk niet gehaald hebben. Met betrekking tot de positiegerelateerde kenmerken lieten de resultaten zien dat alleen centers hoger scoren op hun positiegerelateerde kenmerken in vergelijking met hun niet-positiegerelateerde kenmerken. Tot slot zijn er dit hoofdstuk ontwikkelingsprofielen weergegeven van individuele spelers die de top in het Nederlandse basketbal gehaald hebben. Er werd geconcludeerd dat er veel variatie is in de ontwikkeling van deze spelers met betrekking tot de multidimensionele kenmerken, zelfs voor spelers van dezelfde positie.

De basketballers in het talentontwikkelingsprogramma trainen vele uren per week waardoor ze een risico lopen op het ontstaan van blessures. Met name een voorste kruisband blessure is een veelvoorkomende blessure in het basketbal. Om de negatieve gevolgen van deze blessure op de individuele ontwikkeling van spelers zoveel mogelijk te beperken is er in **hoofdstuk 7** een literatuuronderzoek uitgevoerd. In dit onderzoek is een overzicht weergegeven van psychosociale kenmerken (bijvoorbeeld het stellen van doelen) en interventies (bijvoorbeeld ontspanningssessies) die een positieve invloed kunnen uitoefenen op het herstelproces van een voorste kruisband blessure.

Tot slot werden in **hoofdstuk 8** de algemene discussiepunten, conclusies en praktische implicaties voor coaches en trainers van talentvolle jeugdige basketballers besproken. De conclusie die getrokken kon worden is dat de antropometrische kenmerken van spelers zich ontwikkelen en dat de fysieke en technische kenmerken verbeteren, terwijl reflectie (psychosociaal kenmerk) relatief stabiel blijft gedurende de leeftijd van 13 tot 20 jaar. Het hoofdstuk wordt beëindigd met drie aanbevelingen voor de basketbalpraktijk:

- Pas de hoogte van de basket aan aan de lengte van spelers bij het U12 team (2.43 m), U14 team (2.62 m) en het U16 team (2.84 m).

- Stimuleer de reflectie van basketballers, aangezien resultaten van dit proefschrift hebben aangetoond dat reflectie een belangrijk kenmerk is voor spelers van alle posities om de top te halen.

- Monitor de multidimensionele prestatiekenmerken van basketballers longitudinaal waarbij rekening wordt gehouden met individuele verschillen tussen spelers binnen een team.

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‘Waarom moeilijk doen als het samen kan’ - Loesje

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Liefs Sanne

Curriculum Vitae

Sanne te Wierike werd geboren op 09 oktober 1988 te Enter (gemeente Wierden). Na het behalen van haar VWO diploma aan de Pius X in Almelo (2001 – 2007) is ze in 2007 naar Groningen verhuisd om te starten met de opleiding Bewegingswetenschappen aan de Rijksuniversiteit Groningen. In 2012 heeft ze deze studie succesvol afgerond en in 2013 werd haar afstudeerproject vervolgd met de start van het promotietraject bij het Centrum voor Bewegingswetenschappen. Het onderzoek was gericht op de ontwikkeling van talentvolle basketballers op weg naar de top. Naast dit onderzoek was Sanne gedurende haar promotietraject ook betrokken bij diverse onderwijstaken zoals het begeleiden van reviews, afstudeerprojecten en vakken als Sport, Learning and Performance en Talent Identification & Development in Sports.

Momenteel werkt Sanne aan de Erasmus Universiteit Rotterdam waarbij een richtlijn ontwikkeld wordt over de motorische ontwikkeling van kinderen. Vanaf september 2016 is ze op zoek naar een nieuwe uitdaging in het onderzoek en/of onderwijs gerelateerd aan de (top)sport of gezondheidszorg.

Lijst met publicaties

Internationale publicaties in peer-reviewd journals

te Wierike SCM, Elferink-Gemser MT, Tromp EJY, Vaeyens R, & Visscher C (2015), Role of maturity timing in selection procedures and in the specialization of playing positions in youth basketball. Journal of Sports Sciences, 33(4): 337-345.

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